

**MAC-MSGRAP 1.3.5-1  
Revision 2**

**Monticello Mill Tailings Site  
Operable Unit III**

# **Interim Remedial Action Surface Water and Ground Water Monitoring Plan**

**July 1999**

MRAP OU III AR 617 6-7 INTERIM REMEDIAL ACTION  
INTERIM REMEDIAL ACTION SURFACE WATER AND  
GROUND WATER MONITORING PLAN 7/99



**U.S. Department  
of Energy**

**Monticello Mill Tailings Site  
Operable Unit III**

**Interim Remedial Action  
Surface Water and Ground Water  
Monitoring Plan**

**Revision 2**

**July 1999**

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## Acronyms

|       |                                          |
|-------|------------------------------------------|
| DOE   | U.S. Department of Energy                |
| EA    | Environmental Assessment                 |
| EPA   | U.S. Environmental Protection Agency     |
| FS    | Feasibility Study                        |
| ft    | feet                                     |
| GJO   | Grand Junction Office                    |
| HDPE  | high-density polyethylene                |
| in.   | inches                                   |
| IRA   | Interim Remedial Action                  |
| MMTS  | Monticello Mill Tailings Site            |
| NTU   | nephelometric turbidity unit             |
| OU    | Operable Unit                            |
| pCi/L | picocuries per liter                     |
| QA    | Quality Assurance                        |
| QC    | Quality Control                          |
| RI    | Remedial Investigation                   |
| SDWA  | Safe Drinking Water Act                  |
| UDEQ  | Utah Department of Environmental Quality |
| µm    | micron                                   |
| µg/L  | micrograms per liter                     |

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## 1.0 Introduction

The Monticello Mill Tailings Site (MMTS), located in San Juan County, Utah, comprises several tracts of land, including the Monticello Millsite, the former Bureau of Land Management compound, the South Site, and 25 peripheral properties surrounding the Millsite (Figure 1-1). The U.S. Department of Energy (DOE) owns the former three tracts and several of the peripheral properties. Either entities or individuals own the remaining peripheral properties.

Remediation of the Millsite has been divided into three operable units (OUs). OU I consists of the excavation of mill tailings and other hazardous substances from the Millsite and their containment in a permanent repository. OU II consists of the remediation of radioactively contaminated soils, by-product materials, and hazardous substances from private and DOE-owned properties peripheral to the Millsite. OU III encompasses contaminated surface water and ground water at and downgradient of the Monticello Millsite. Contaminated soil and sediment deposited downstream of the Millsite in and adjacent to Montezuma Creek were studied and remediated as part of OU III.

Ground water samples collected from wells completed in the alluvial aquifer have elevated concentrations of various metals, uranium-decay series radionuclides, sulfate, and nitrate. Arsenic, manganese, molybdenum, selenium, vanadium and lead-210 have been transported through the alluvial aquifer and have contaminated the ground water at downgradient locations on private property east of the Millsite. Selenium, nitrate, and radium were detected in concentrations above regulatory standards on the Millsite only. Molybdenum and uranium were detected in concentrations above regulatory standards both on the Millsite and downgradient of the Millsite.

In Montezuma Creek, elevated concentrations of arsenic, copper, selenium, and sulfate are generally limited to the Millsite or just downstream of the Millsite boundary. Molybdenum, radon-222, and vanadium have been detected at elevated concentrations over a larger extent downstream but generally reach background concentrations within 2 miles of the eastern Millsite boundary. Uranium and manganese concentrations are elevated throughout the OU III area.

During the period from November 1992 through October 1996, monitoring of the OU III surface water and ground water was conducted in accordance with the *Monticello Mill Tailings Site, Operable Unit III, Remedial Investigation/ Feasibility Study Work Plan* (DOE 1995a); the *Monticello Mill Tailings Site, Operable Unit III, Remedial Investigation/Feasibility Study Quality Assurance Project Plan* (DOE 1995b); and the *Monticello Mill Tailings Site, Operable Unit III, Remedial Investigation/ Feasibility Study Field Sampling Plan* (DOE 1995c) including Program Directives that modified these plans. The results of these monitoring efforts are documented in the *Monticello Mill Tailings Site, Operable Unit III, Remedial Investigation* (OU III RI) (DOE 1998a). In 1997 and 1998, during preparation of the OU III RI and the *Record of Decision for an Interim Remedial Action at the Monticello Mill Tailings Site, Operable Unit III—Surface Water and Ground Water, Monticello, Utah*, (DOE 1998b), the *Monticello Mill Tailings Site, Operable Unit III, Annual Monitoring Program* (DOE 1997) was implemented to provide information on and document changes in surface-water and ground-water quality, ground-water levels, and stream flow during the implementation of Millsite excavation.

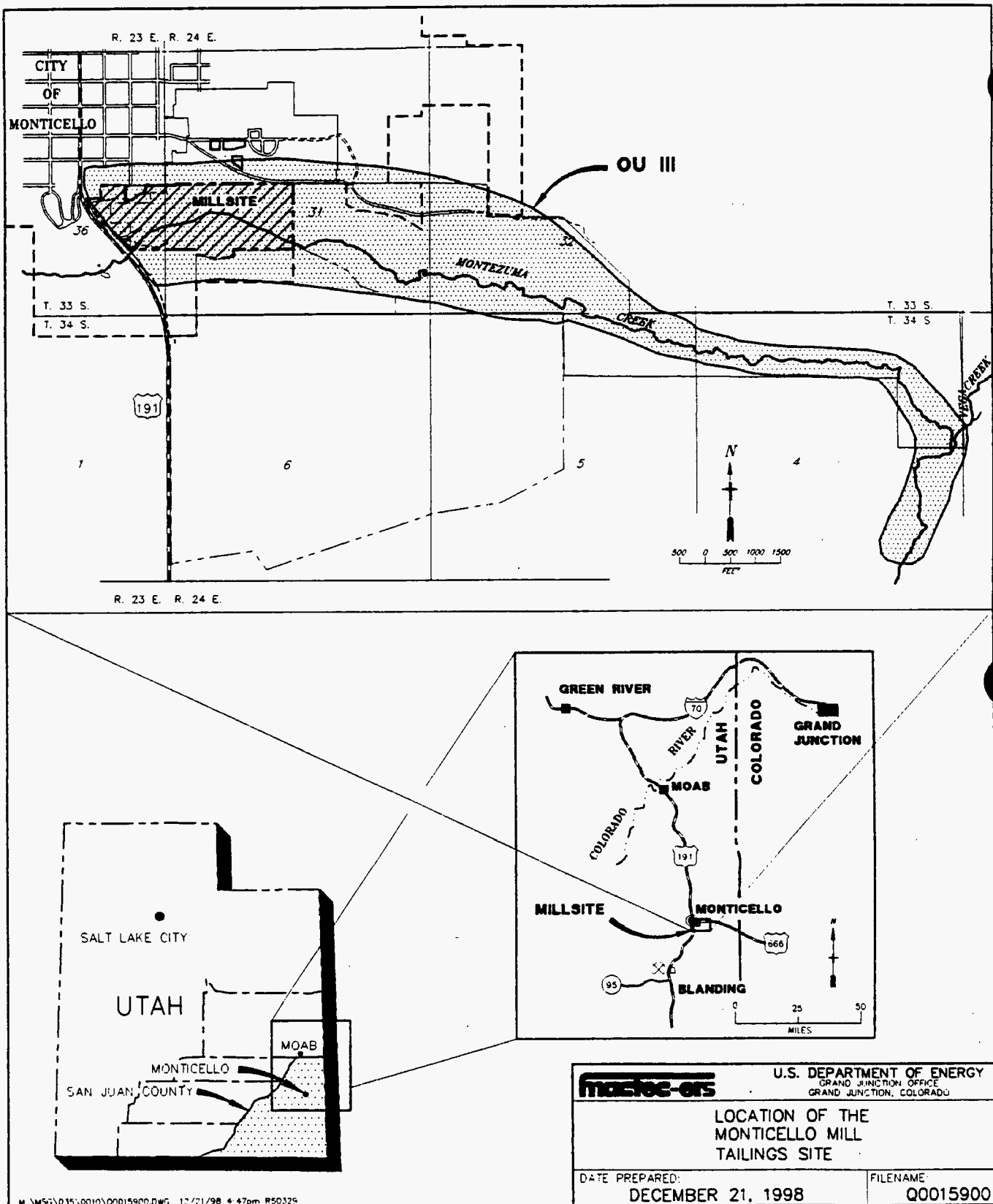


Figure 1-1. Monticello Mill Tailings Site, San Juan County, Utah

This annual monitoring plan presents a surface-water and ground-water monitoring program to be implemented during the OU III interim remedial action (IRA). Monitoring is a requirement of the data collection and PeRT wall treatability study components of the IRA which are specified in the *Monticello Mill Tailings Site, Operable Unit III, Interim Remedial Design/Remedial Action (RD/RA) Work Plan for Operable Unit III—Surface Water and Ground Water* (DOE 1999a). This plan revises the monitoring program that was conducted during 1997 and 1998 by increasing the frequency of the monitoring events and increasing the number of water quality sampling locations east of the Millsite. This document is intended to provide field personnel with the information necessary to collect monitoring data and water samples that will fulfill the relevant data requirements during the IRA. If the results of any of the sampling events specified in this program indicate that significant changes are occurring in water quality and or water level and flow direction, then revisions to this program will be considered and discussed with the U.S. Environmental Protection Agency (EPA) and the Utah Department of Environmental Quality (UDEQ) prior to implementation.



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## 2.0 Objectives

The objectives of this surface-water and ground-water monitoring program are to provide the information needed for the data collection and PeRT wall treatability study components of the IRA. A comprehensive discussion of the objectives and scope of the IRA components is presented in the *Monticello Mill Tailings Site, Operable Unit III, Interim Remedial Action Work Plan* (OU III IRA Work Plan) (DOE 1999b). Objectives of data collection are to provide information on water quality, water levels, and stream flow that will be used in the final OU III feasibility study and remedial alternative selection.

Objectives of the PeRT wall treatability study are to evaluate the effectiveness of the PeRT wall system in reducing the concentrations of contaminants, determine the amount of leaching of iron and manganese from the zero-valent iron, evaluate the longevity of the PeRT wall system, and to evaluate the effectiveness of the slurry wall to capture and divert water to the gate.

### 2.1 Contaminants of Concern

The ground water contaminants of concern (COCs) identified during the human health risk assessment performed as part of the remedial investigation were

|                 |             |            |           |
|-----------------|-------------|------------|-----------|
| Arsenic         | Manganese   | Selenium   | Uranium   |
| Vanadium        | Lead-210    | Radium-226 | Radon-222 |
| Uranium-234/238 | Gross Alpha | Gross Beta |           |

Nitrate and molybdenum were added to the list because, although they do not cause significant risk, they do exceed established standards for ground water. Similarly, copper was added because historically it has exceeded the established standard for surface water at some locations on the Millsite. Cobalt, lead, and zinc are on the list because they were never formally deleted as COCs for OU III. The complete list of COCs are listed in Table 2.1-1 along with the preliminary remediation goals for ground water that were proposed in the draft *Monticello Mill Tailings Site Operable Unit III Feasibility Study of Surface Water and Groundwater* (DOE 1998c) or benchmarks that were used in the OU III ecological risk assessment (see Volume VII of the OU III RI, DOE 1998a).

Table 2.1-1 Preliminary Remediation Goals

| COC                                    | Risk-Based                       | ARAR-Based                                    |
|----------------------------------------|----------------------------------|-----------------------------------------------|
| Arsenic                                | 5 to 29 µg/L <sup>1</sup>        | 50 µg/L <sup>2,3,4</sup>                      |
| Cobalt                                 | —                                | 3.0 µg/L <sup>8</sup>                         |
| Copper                                 | —                                | 39 µg/L <sup>7</sup>                          |
| Lead                                   | —                                | 19 µg/L <sup>7</sup>                          |
| Manganese                              | 4,300 to 7,700 µg/L <sup>5</sup> | 500 µg/L <sup>4</sup>                         |
| Molybdenum                             | —                                | 100 µg/L <sup>3</sup>                         |
| Nitrate                                | —                                | 10 mg/L <sup>2,3,4</sup>                      |
| Selenium                               | 160 to 290 µg/L <sup>5</sup>     | 50 µg/L <sup>2,4</sup> ; 10 µg/L <sup>3</sup> |
| Uranium                                | 92 to 170 µg/L <sup>5</sup>      | 44 µg/L <sup>3</sup>                          |
| Vanadium                               | 220 to 400 µg/L <sup>5</sup>     | 8 µg/L <sup>4</sup>                           |
| Zinc                                   | —                                | 340 µg/L <sup>7</sup>                         |
| Lead-210                               | 2 to 8 pCi/L <sup>6</sup>        | 0.5 pCi/L <sup>4</sup>                        |
| Radium-226                             | 5 to 28 pCi/L <sup>6</sup>       | 5 pCi/L <sup>2,3,4</sup>                      |
| Radon-222                              | —                                | 300 pCi/L <sup>9</sup>                        |
| Thorium-230                            | —                                | 1.0 <sup>4</sup>                              |
| Uranium-234/238                        | 39 to 160 pCi/L <sup>6</sup>     | 30 pCi/L <sup>3</sup>                         |
| Gross Alpha (minus radium and uranium) | —                                | 15 pCi/L <sup>2,3,4</sup>                     |
| Gross Beta                             | —                                | 4 mrem <sup>2,4</sup>                         |

<sup>1</sup>Based on carcinogenic nonradionuclide risk<sup>2</sup>Based on the Safe Drinking Water Act (SDWA)<sup>3</sup>Based on the Uranium Mill Tailing Radiation Control Act<sup>4</sup>Based on Utah Ground-Water Standards<sup>5</sup>Based on noncarcinogenic risk<sup>6</sup>Based on carcinogenic radionuclide risk<sup>7</sup>Utah Surface Water Aquatic Wildlife Standard<sup>8</sup>ECO Update, Ecotox Thresholds, Intermittent Bulletin, Vol. 3, No. 2 (EPA 1996)<sup>9</sup>SDWA proposed

### 3.0 Water Sampling Locations and Frequency

As specified in the *Monticello Mill Tailings Site, Operable Unit III, Annual Monitoring Program* (DOE 1997), the semiannual sampling program consisted of sampling six monitoring wells and four surface-water locations in April 1998 and 24 monitoring wells and eight surface-water locations sampled in October 1997 and 1998. These ground-water and surface-water samples were collected on a variable schedule from sampling locations specified in Table 2-1 under the column "Annual Monitoring Events."

#### 3.1 Interim Remedial Action Data Collection Events

Under this plan, (beginning in 1999) 16 monitoring wells and six surface-water locations will be sampled biannually in January and July, 26 monitoring wells and 10 surface-water locations will be sampled in April, and 40 monitoring wells and 11 surface-water locations will be sampled in October. These ground-water and surface-water samples will be collected on a variable schedule from sampling locations specified in Table 3.1-1 under the column "Interim Remedial Action Data Collection Events" and shown in Figures 3.1-1 and 3.1-2.

Of the locations tallied above, three new surface-water sampling locations were selected on the Millsite for sampling beginning in January 1999. These locations were selected after considering previous source areas and current field observations. Five temporary wells were installed on the Millsite during February 1999. These five wells will be sampled (unless dry) during the quarterly sampling in 1999 to determine if permanent well installations are warranted in those areas. One new surface-water sampling location was selected downstream of where significant soil and sediment remediation (downstream of E 30500) was performed during 1998 for sampling beginning in April 1999. Additional surface-water and ground-water sampling locations will be added to the quarterly monitoring program through the issuance of Program Directives in response to changes in the Montezuma Creek channel due to excavation and restoration activities and in association with well installation activities planned for October 1999.

The following information was considered in designing the sampling network. During the fall, Montezuma Creek exhibits base flow conditions, water levels in the alluvial system are generally the lowest, and contaminant levels are generally highest in both surface water and ground water. Therefore, an October sampling event is designed to be the most extensive sampling round. Locations west of U.S. Highway 191 and throughout the OU III study area will be monitored in October, including monitoring wells completed in the alluvial aquifer, the Burro Canyon, Dakota Sandstone, and Mancos Shale Formations, and surface water in Montezuma Creek.

During the spring, Montezuma Creek exhibits high-flow conditions, water levels in the alluvial aquifer are generally the highest, and contaminant levels are generally lowest in both surface water and ground water. An April sampling event was chosen to coincide with these flow/water level conditions. Monitoring during April will not be as extensive as during the October event; areas upgradient and crossgradient of the former Millsite and Burro Canyon monitoring wells east of well 92-10 will not be sampled. These areas are not included in the April sampling because previous sampling results indicate that the ground-water quality does not fluctuate significantly during the year and, in the case of the far downgradient Burro Canyon wells where artesian conditions occur, remediation at the Millsite is not expected to impact the water quality.

Table 3.1-1 Ground-Water and Surface-Water Sampling Locations and Frequency for Data Collection

| SAMPLING LOCATION |                  |                    | ANNUAL MONITORING EVENTS |         | INTERIM REMEDIAL ACTION DATA COLLECTION EVENTS <sup>a</sup> |       |         |
|-------------------|------------------|--------------------|--------------------------|---------|-------------------------------------------------------------|-------|---------|
| General Location  | Description      | Location ID        | April                    | October | January July                                                | April | October |
| Upgradient        | Alluvial         | 92-05              |                          | X       |                                                             |       | X       |
|                   | Burro Canyon     | 92-06              |                          | X       |                                                             |       | X       |
|                   | Dakota Sandstone | 92-13              |                          | X       |                                                             |       | X       |
|                   | Montezuma Creek  | SW92-03            |                          | X       |                                                             |       | X       |
| Millsite          | Alluvial         | 82-20              |                          | X       |                                                             |       | X       |
|                   | Alluvial         | GB1126T            |                          |         | X <sup>b</sup>                                              | X     | X       |
|                   | Alluvial         | GB1227T            |                          |         | X <sup>b</sup>                                              | X     | X       |
|                   | Alluvial         | GB1690T            |                          |         | X <sup>b</sup>                                              | X     | X       |
|                   | Alluvial         | GB2820T            |                          |         | X <sup>b</sup>                                              | X     | X       |
|                   | Alluvial         | GB3127T            |                          |         | X <sup>b</sup>                                              | X     | X       |
|                   | Burro Canyon     | 93-01              |                          | X       |                                                             |       | X       |
|                   |                  | 31SW93-200-1       |                          | X       |                                                             |       | X       |
|                   | Dakota Sandstone | 31SW93-200-2       |                          | X       |                                                             |       | X       |
|                   | Mancos Shale     | 31SW93-200-3       |                          | X       |                                                             |       | X       |
|                   |                  | 31SW93-200-4       |                          | X       |                                                             |       | X       |
|                   | Montezuma Creek  | SW99-01            |                          |         | X                                                           | X     | X       |
|                   | Surface Water    | SW99-02            |                          |         | X                                                           | X     | X       |
|                   |                  | SW99-03            |                          |         | X                                                           | X     | X       |
| Downgradient      | Alluvial         | 82-07              | X                        | X       | X                                                           | X     | X       |
|                   |                  | 82-08              |                          |         | X                                                           | X     | X       |
|                   |                  | 82-09 <sup>c</sup> |                          |         | X                                                           | X     | X       |
|                   |                  | 88-85              | X                        | X       | X                                                           | X     | X       |
|                   |                  | 92-07 <sup>d</sup> |                          | X       | X                                                           |       |         |
|                   |                  | 92-08              |                          |         | X                                                           | X     | X       |
|                   |                  | 92-09              | X                        | X       |                                                             | X     | X       |
|                   |                  | 92-11              | X                        | X       | X                                                           | X     | X       |
|                   |                  | 95-01              | X                        | X       |                                                             | X     | X       |
|                   |                  | 95-03              | X                        | X       |                                                             | X     | X       |

<sup>a</sup>IRA sampling events are those established by this document; sampling to be initiated in 1999.

<sup>b</sup>Temporary wells were installed and initial sampling occurred in February 1999.

<sup>c</sup>Well 82-09 is located within a bull elk pen. Sampling of this well will not occur if the elk are present. Contact owner one week prior to sampling to make arrangements for removing the elk.

<sup>d</sup>Well 92-07 was damaged in June 1999. Sampling will be attempted in July 1999 and discontinued thereafter.

**Table 3.1-1 Ground-Water and Surface-Water Sampling Locations and Frequency for Data Collection**  
(continued)

| SAMPLING LOCATION |                     |               | ANNUAL MONITORING EVENTS |         | INTERIM REMEDIAL ACTION DATA COLLECTION EVENTS <sup>a</sup> |       |         |
|-------------------|---------------------|---------------|--------------------------|---------|-------------------------------------------------------------|-------|---------|
| General Location  | Description         | Location ID   | April                    | October | January July                                                | April | October |
| Downgradient      | Alluvial            | P92-01        |                          |         |                                                             | X     | X       |
|                   |                     | P92-02        |                          | X       |                                                             | X     | X       |
|                   |                     | P92-03        |                          |         |                                                             | X     | X       |
|                   |                     | P92-04        |                          | X       | X                                                           | X     | X       |
|                   |                     | P92-05        |                          |         | X                                                           | X     | X       |
|                   |                     | P92-06        |                          |         | X                                                           | X     | X       |
|                   |                     | P92-07        |                          |         | X                                                           | X     | X       |
|                   |                     | P92-09        |                          |         | X                                                           | X     | X       |
|                   | Burro Canyon        | 95-02         |                          | X       |                                                             |       | X       |
|                   |                     | 95-04         |                          | X       |                                                             |       | X       |
|                   |                     | 95-06         |                          | X       |                                                             | X     | X       |
|                   |                     | 95-08         |                          | X       |                                                             |       | X       |
|                   |                     | 31NE93-205    |                          | X       |                                                             |       | X       |
|                   |                     | 92-10         |                          | X       |                                                             | X     | X       |
|                   | Burro Canyon/Dakota | 83-70         |                          | X       |                                                             | X     | X       |
|                   | Dakota Sandstone    | 92-12         |                          | X       |                                                             | X     | X       |
|                   |                     | 95-07         |                          | X       |                                                             |       | X       |
|                   | Montezuma Creek     | W-4           | X                        | X       | X <sup>b</sup>                                              |       |         |
|                   |                     | SW92-06       | X                        | X       | X                                                           | X     | X       |
|                   |                     | Sorenson Site | X                        | X       | X                                                           | X     | X       |
|                   |                     | SW92-07       | X                        | X       |                                                             | X     | X       |
|                   |                     | SW92-08       |                          | X       |                                                             | X     | X       |
|                   |                     | SW92-09       |                          |         |                                                             | X     | X       |
|                   |                     | SW94-01       |                          |         |                                                             | X     | X       |
|                   |                     | SW99-04       |                          |         | X <sup>c</sup>                                              | X     | X       |

<sup>a</sup>IRA sampling events are those established by this document; sampling to be initiated in 1999.

<sup>b</sup>The last sampling of W-4 occurred in January 1999; subsequent to that sampling, Montezuma Creek was remediated and flow contained within pipe in that area.

<sup>c</sup>The first sampling at SW99-04 occurred in April 1999.

The April sampling event includes all alluvial monitoring wells and surface-water sampling locations downgradient of the Millsite.

During January and July, sampling will focus on surface-water locations on the Millsite and alluvial wells and surface-water locations downgradient of the site. These locations are sampled during each quarterly sampling event and are expected to most quickly reflect changes brought on by source removal at the Millsite or excavation activities.

As shown in Table 3.1-1, the data collection sampling strategy has not changed from that which was implemented during 1997 and 1998. Ground-water and surface-water quality upgradient of former tailings piles is well characterized. Annual sampling of these locations in October is sufficient to monitor for major changes in quality of water entering the site.

Downgradient of the Millsite, the data collection sampling strategy is similar to that which was implemented during 1997 and 1998, however, the frequency of sampling and the number of alluvial monitoring wells to be sampled has increased. These changes were made in anticipation of changes that may be seen in ground-water quality and flow direction and will provide data necessary to update ground-water flow and transport modeling performed in support of a remedial alternative evaluation in the OU III Feasibility Study (DOE 1998c).

### **3.2 Permeable Reactive Treatment Wall Ground-Water Sampling**

Ground-water monitoring activities associated with the permeable reactive treatment (PeRT) wall are monitoring treatment performance of the PeRT wall and monitoring performance of the slurry walls. The effectiveness of the PeRT slurry walls in capturing and diverting ground water to the gate will be evaluated by monitoring ground-water levels (Section 4.6) and conducting a tracer test. A second tracer study will be conducted to aid in understanding the ground-water flow patterns and residence time through the PeRT wall. Using tracer travel times and ground-water elevation data, the volumetric flow rate passing through the gate will be estimated. Monitoring activities associated with this tracer study will be added by issuing a Program Directive after the results of the slurry wall tracer test are evaluated. Monitoring wells will be installed using the Geoprobe System after PeRT wall installation is complete (planned for July 1999). Well installation procedures are described in the OU III IRA Work Plan (DOE 1999b).

#### **3.2.1 PeRT Wall Performance Monitoring**

The performance of the PeRT wall as a treatment technology will be evaluated by measuring water levels (discussed in Section 4.6) and collecting ground-water samples at 55 well locations, including 7 upgradient of the wall, 36 within the reactive media, and 12 downgradient of the wall. Six locations will have dual-completion wells forming a transect passing through the center of the reactive media (parallel to groundwater flow). Therefore, there are actually 61 wells in the monitoring well network. One dual-completion well will be located upgradient of the PeRT wall, four within the wall, and one downgradient of the PeRT wall. Water sampling of these wells is scheduled for September, October, and November 1999 and then quarterly, concurrent with the Data Collection Sampling (Section 3.1) beginning in January 2000. The location of the wells to be sampled to evaluate the PeRT wall as a treatment technology are shown in Figure 3.2.1-1.



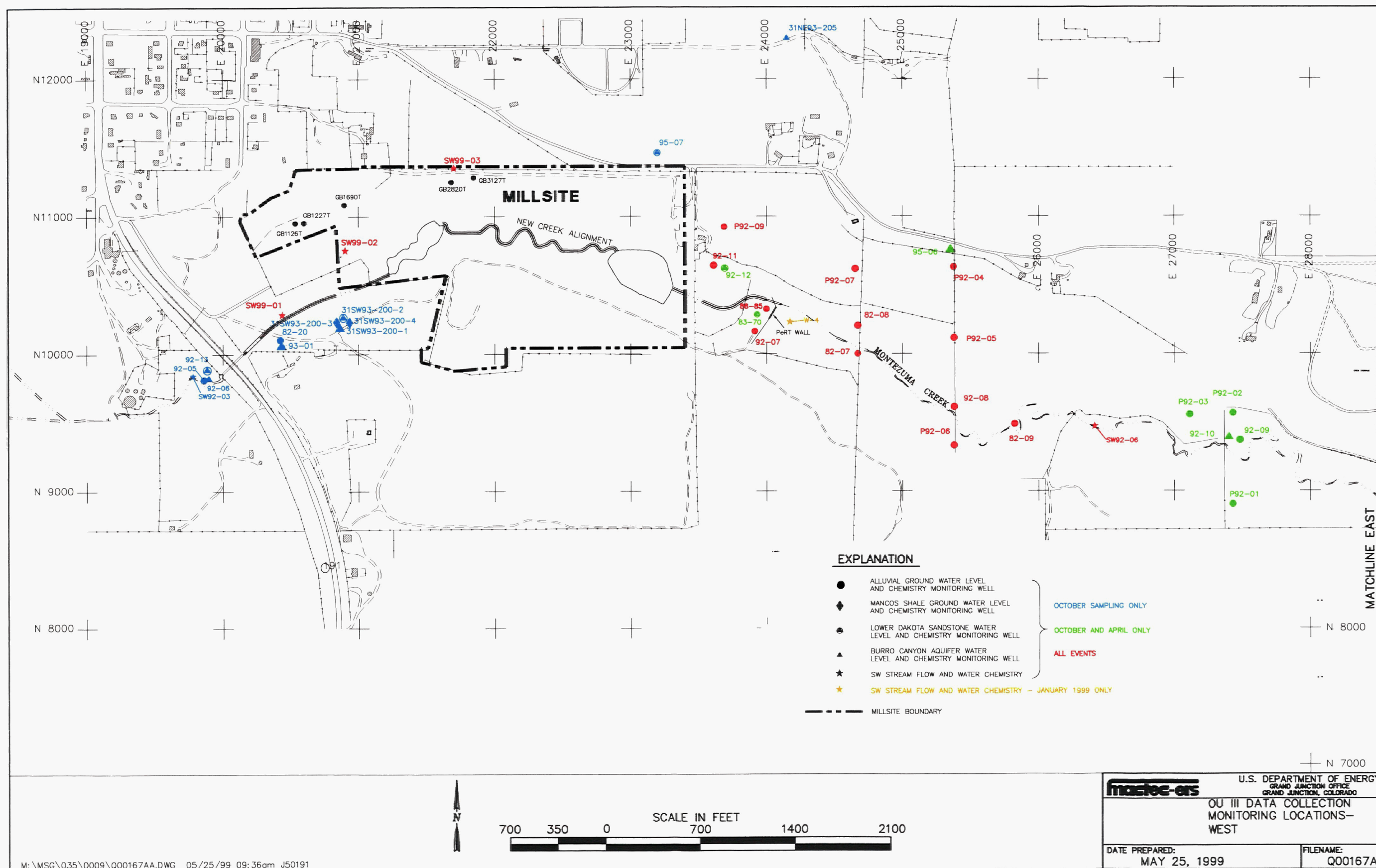


Figure 3.1-1. Ground-Water and Surface-Water Monitoring Network—West



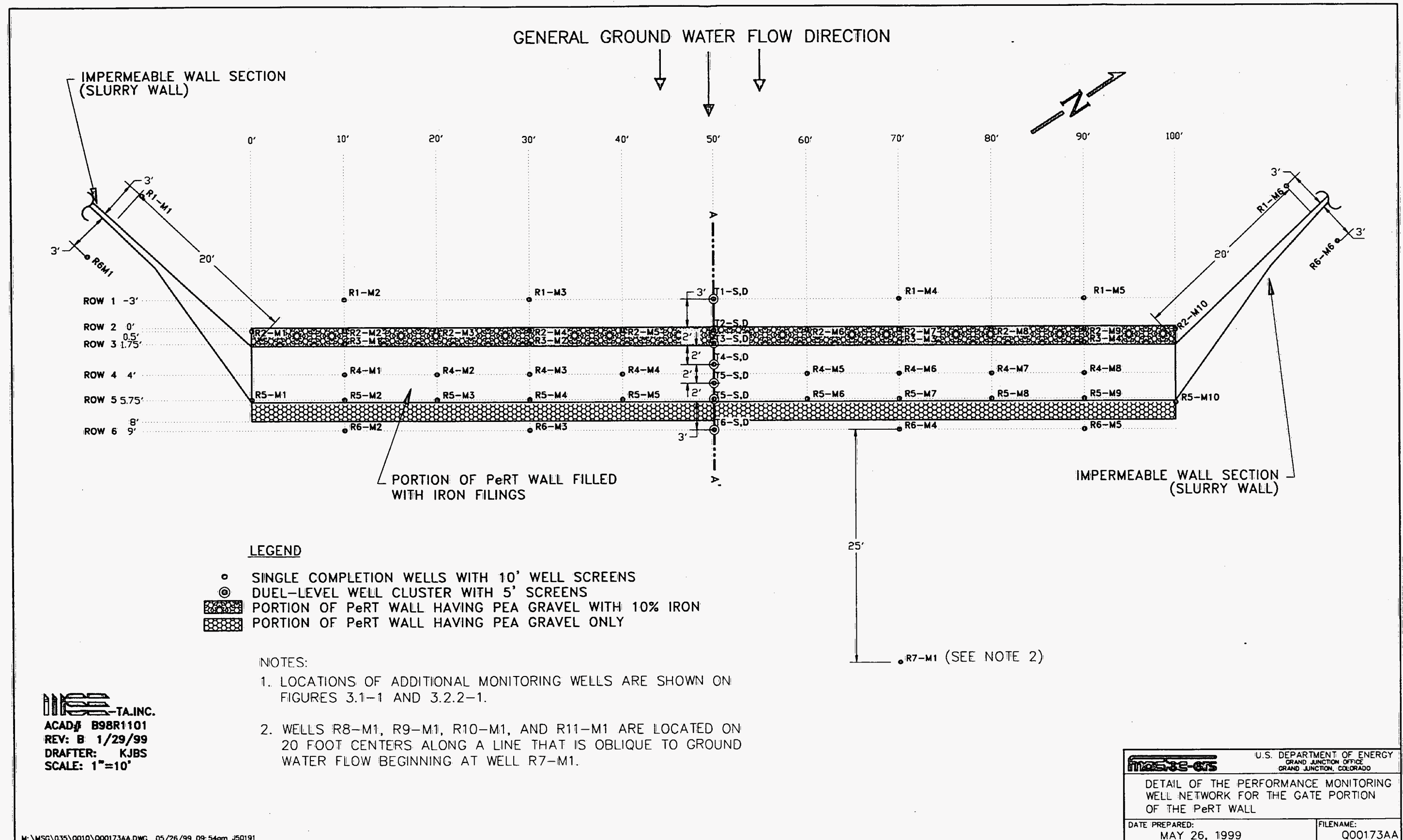


Figure 3.2.1-1. PeRT Wall Performance Monitoring Well Network

During each sampling event, samples will be collected from all 61 PeRT wall monitoring wells for metals analysis. Samples will also be collected during each sampling event from some of these monitoring wells for anion, cation, iron, and manganese analyses. Radium-226 analysis will be performed on samples collected from some monitoring wells during three sampling events. Table 3.2.1-1 specifies for each monitoring well the frequency of sample collection for each of the analyses that are to be performed.

In addition to the 61 PeRT wall performance monitoring wells, ground-water samples will be collected quarterly from existing wells 92-11 and 88-85 located approximately 500 ft and 70 ft, respectively, upgradient of the wall and at P92-07, 82-08 and 82-07 located approximately 700 to 900 ft downgradient of the wall. Additionally, samples will be collected quarterly from four wells that are proposed for installation in October 1999 located approximately 300 ft downgradient of the wall. If changes are needed to the sampling strategy proposed in Table 3.2.1-1, Program Directives will be issued to redirect field sampling activities.

The following rationale was used to design the PeRT wall performance monitoring network. To determine the contaminant removal efficiency for arsenic, molybdenum, selenium, uranium, and vanadium, well installation and sampling for metals analyses is planned upgradient, within, and immediately downgradient of the PeRT wall. The dual-level well installations across one transect of the reactive media will be used to help evaluate PeRT wall performance as a function of depth. Because these are primary objectives of the PeRT wall treatability study, all monitoring wells will be sampled during every event.

To determine if iron and manganese are leaching from the zero valent iron, concentrations of iron and manganese will be measured in samples collected along three transects of the reactive media, at downgradient wells located in a row 1 foot from the reactive media, at downgradient wells located starting about 25 ft from the center of the reactive media, and then on 20-ft centers along a 100-ft line oblique to the direction of ground-water flow.

Information about the tendency for the PeRT wall to clog due to mineral precipitation within the zero valent iron media will be obtained by monitoring ground water levels across the wall over time. If water levels indicate that the gradient across the PeRT wall reactive media is increasing, the clogging may be occurring reducing the hydraulic conductivity. Sample results will provide data to estimate the amount of mineral precipitation in the reactive media. Water-level measurements are further discussed in Section 4.6.

Performance of the ZVI reactive media could be affected by physical and chemical parameters of the ground water. The parameters pH, Eh, dissolved oxygen, temperature, electrical conductivity, and major cations and anions will be monitored. Field parameter measurements are further discussed in Section 3.2.2.

### **3.2.2 Slurry Wall Tracer Test Monitoring**

A slurry wall tracer test will be conducted to determine if leakage is occurring through or beneath the slurry walls. Tracer movement will be monitored at 26 locations, corresponding to the six wells adjacent to the upgradient sides of the walls, the two upgradient performance monitoring wells at the corners of the gate, four wells east of the north wall, and 14 wells east of the south

wall as shown in Figure 3.2.2-1. Monitoring will begin one week after the bromide tracer is injected and will continue on a weekly basis until the tracer is detected at the upgradient corners of the reactive media. Samples will be collected for bromide analysis by ion chromatography (see Sections 5.1 and 5.2).

Table 3.2.1-1 PeRT Wall Performance Monitoring Schedule

| Well No. | September/October/November 1999 |                                                                              |                     |                     | IRA Annual Monitoring (Quarterly Sampling) |                                                                              |                     |                     |
|----------|---------------------------------|------------------------------------------------------------------------------|---------------------|---------------------|--------------------------------------------|------------------------------------------------------------------------------|---------------------|---------------------|
|          | Metals<br>(As, Mo, Se, U,<br>V) | Anions/Cations<br>(Cl, NO <sub>3</sub> , SO <sub>4</sub> ,<br>Ca, K, Mg, Na) | Iron &<br>Manganese | Ra-226 <sup>a</sup> | Metals<br>(As, Mo, Se, U,<br>V)            | Anions/Cations<br>(Cl, NO <sub>3</sub> , SO <sub>4</sub> ,<br>Ca, K, Mg, Na) | Iron &<br>Manganese | Ra-226 <sup>b</sup> |
| R1-M1    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     | X                   |
| R1-M2    | X                               | X                                                                            | X                   | X                   | X                                          | X                                                                            | X                   |                     |
| R1-M3    | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R1-M4    | X                               | X                                                                            |                     |                     | X                                          | X                                                                            |                     |                     |
| R1-M5    | X                               |                                                                              |                     | X                   | X                                          |                                                                              |                     | X                   |
| R1-M6    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
|          |                                 |                                                                              |                     |                     |                                            |                                                                              |                     |                     |
| R2-M1    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R2-M2    | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R2-M3    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R2-M4    | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R2-M5    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R2-M6    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R2-M7    | X                               | X                                                                            |                     |                     | X                                          | X                                                                            |                     |                     |
| R2-M8    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R2-M9    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R2-M10   | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
|          |                                 |                                                                              |                     |                     |                                            |                                                                              |                     |                     |
| R3-M1    | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R3-M2    | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R3-M3    | X                               | X                                                                            |                     |                     | X                                          | X                                                                            |                     |                     |
| R3-M4    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
|          |                                 |                                                                              |                     |                     |                                            |                                                                              |                     |                     |
| R4-M1    | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R4-M2    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R4-M3    | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R4-M4    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R4-M5    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R4-M6    | X                               | X                                                                            |                     |                     | X                                          | X                                                                            |                     |                     |
| R4-M7    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R4-M8    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |

Table 3.2.1-1 PeRT Wall Performance Monitoring Schedule (continued)

| Well No. | September/October/November 1999 |                                                                              |                     |                     | IRA Annual Monitoring (Quarterly Sampling) |                                                                              |                     |                     |
|----------|---------------------------------|------------------------------------------------------------------------------|---------------------|---------------------|--------------------------------------------|------------------------------------------------------------------------------|---------------------|---------------------|
|          | Metals<br>(As, Mo, Se, U,<br>V) | Anions/Cations<br>(Cl, NO <sub>3</sub> , SO <sub>4</sub> ,<br>Ca, K, Mg, Na) | Iron &<br>Manganese | Ra-226 <sup>a</sup> | Metals<br>(As, Mo, Se, U,<br>V)            | Anions/Cations<br>(Cl, NO <sub>3</sub> , SO <sub>4</sub> ,<br>Ca, K, Mg, Na) | Iron &<br>Manganese | Ra-226 <sup>b</sup> |
| R5-M1    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R5-M2    | X                               | X                                                                            | X                   | X                   | X                                          | X                                                                            | X                   | X                   |
| R5-M3    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R5-M4    | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R5-M5    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R5-M6    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R5-M7    | X                               | X                                                                            |                     |                     | X                                          | X                                                                            |                     |                     |
| R5-M8    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R5-M9    | X                               |                                                                              |                     | X                   | X                                          |                                                                              |                     | X                   |
| R5-M10   | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R6-M1    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R6-M2    | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R6-M3    | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R6-M4    | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R6-M5    | X                               |                                                                              | X                   |                     | X                                          |                                                                              | X                   |                     |
| R6-M6    | X                               |                                                                              |                     |                     | X                                          |                                                                              |                     |                     |
| R7-M1    | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R8-M1    | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R9-M1    | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R10-M1   | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| R11-M1   | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| T1-S     | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| T1-D     | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |

Table 3.2.1-1 PeRT Wall Performance Monitoring Schedule (continued)

| Well No. | September/October/November 1999 |                                                                              |                     |                     | IRA Annual Monitoring (Quarterly Sampling) |                                                                              |                     |                     |
|----------|---------------------------------|------------------------------------------------------------------------------|---------------------|---------------------|--------------------------------------------|------------------------------------------------------------------------------|---------------------|---------------------|
|          | Metals<br>(As, Mo, Se, U,<br>V) | Anions/Cations<br>(Cl, NO <sub>3</sub> , SO <sub>4</sub> ,<br>Ca, K, Mg, Na) | Iron &<br>Manganese | Ra-226 <sup>a</sup> | Metals<br>(As, Mo, Se, U,<br>V)            | Anions/Cations<br>(Cl, NO <sub>3</sub> , SO <sub>4</sub> ,<br>Ca, K, Mg, Na) | Iron &<br>Manganese | Ra-226 <sup>b</sup> |
| T2-S     | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| T2-D     | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| T3-S     | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| T3-D     | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| T4-S     | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| T4-D     | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| T5-S     | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| T5-D     | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| T6-S     | X                               | X                                                                            | X                   |                     | X                                          | X                                                                            | X                   |                     |
| T6-D     | X                               | X                                                                            | X                   | X                   | X                                          | X                                                                            | X                   | X                   |

<sup>a</sup>Ra-226 sample will be collected at this location during September 1999 only.

<sup>b</sup>Location will be sampled July 2000 and July 2001 for Ra-226.

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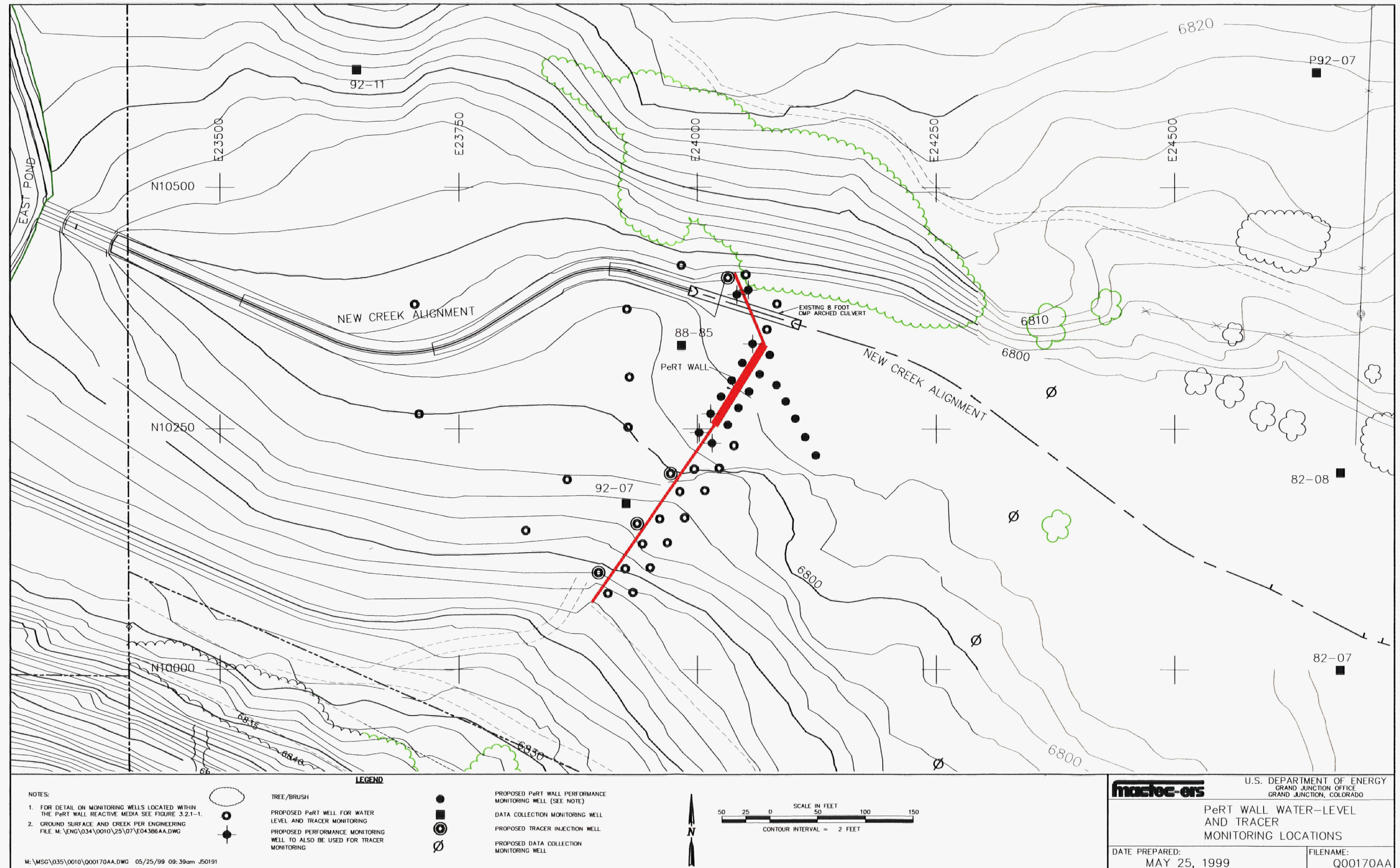


Figure 3.2.2-1. PeRT Wall Water-Level and Tracer Monitoring Locations



## 4.0 Sampling Procedures

### 4.1 Work Area Preparation

Site preparation and equipment handling will be conducted to minimize the potential for cross-contamination of samples and sampling equipment. This may require use of plastic sheeting or wash basins beneath equipment set on the ground or tables, stowing equipment after decontamination in plastic bags, and excluding non-essential personnel or vehicles from the work area.

### 4.2 Well Purging

#### 4.2.1 Well Purge Criteria

Prior to collecting a ground-water sample from a monitoring well, the well will be purged according to the procedural and equipment requirements prescribed in this section. The goal of purging is to remove potentially unrepresentative water from the well casing and filter pack while allowing new formation water to recharge the well in the sampling interval.

Purge water will be managed as follows:

1. Purge water from upgradient alluvial and bedrock wells will be released to the ground at the well site.
2. Contaminated alluvial ground water from Millsite and downgradient wells will be contained and released to Pond 4, if available, or to a designated decontamination facility.
3. Purge water from all other bedrock wells will be contained and then released to the ground at the well site if field parameter values are consistent with previous measurements. If not, the water will be released to Pond 4, if available, or to a designated decontamination facility.

The depth to ground water will be initially measured with an electric sounder before purging the well (GJO Procedure LQ-2[T] of the GJO Environmental Procedures Catalog [WASTREN-GJ and MACTEC-ERS 1996]; Appendix A). Well depth, casing diameter, radius of well bore, and depth to water will be used to calculate the volume of water in the borehole. Well completion logs (Appendix B) will be available in the field to provide the correct dimensions for volume calculations.

The volume of water to be purged from wells has been revised from the criteria in the "Standard Practice for Purging of Monitoring Wells" (GJO Procedure LQ-3[P], Appendix A). One of four purging methods will be used. These methods include 1) purging a minimum of one borehole volume and field parameter stabilization (conventional purging), 2) low-flow purging and field parameter stabilization, and 3) purge until the well is dry. The fourth method will only be used at the PeRT wall performance and tracer monitoring wells. At these wells, sample collection can begin after one tubing volume has been removed.

In the first method, sample collection will begin after a minimum of one borehole volume has been evacuated and measured field parameters will have stabilized. A minimum of one reading of each field measurement will be recorded approximately every one-sixth borehole volume calculated. The borehole volume is determined according to the following equations:

$$\text{Casing Volume (gallons)} = \frac{(r/12)^2 \times \pi \times (h_1 - h_2) \times 7.48}{7.48}, \text{ where}$$

- $r$  = radius of well casing (inch [in.]),
- $\pi$  = 3.14,
- $h_1$  = depth of well (feet [ft]) from top of well casing,
- $h_2$  = depth to water (ft) from top of well casing,
- 7.48 = gallons per cubic ft.

$$\text{Filter Pack Volume (gallons)} = \begin{cases} [(r_2/12)^2 - (r_1/12)^2] \times \pi \times (h_3 - h_2) \times 7.48 \times 0.30, & \text{if } h_1 < h_2, \text{ or} \\ [(r_2/12)^2 - (r_1/12)^2] \times \pi \times (h_3 - h_1) \times 7.48 \times 0.30, & \text{if } h_1 > h_2, \text{ where} \end{cases}$$

- $r_1$  = radius of well casing (in.),
- $r_2$  = radius of well bore (in.),
- $\pi$  = 3.14,
- $h_1$  = depth to water (ft) from top of well casing,
- $h_2$  = depth to top of filter pack (ft) from top of well casing,
- $h_3$  = depth of well (ft) from top of well casing,
- 7.48 = gallons per cubic ft, and
- 0.30 = estimated porosity of filter pack (30 percent).

$$\text{Borehole Volume} = \text{Casing Volume} + \text{Filter Pack Volume}$$

The second purging method involves pumping at a low flow rate (<0.125 gallons per minute [gal/min]) with a dedicated pump. In theory, the slow pumping rate will allow water to flow directly from the formation to the pump intake. The slow pumping rate will result in minimal mixing with the stagnant water column above the pump intake, minimal pumping-induced turbidity, and minimal disturbance of sediment collected in the end cap of the well.

Wells with dedicated pumps or dedicated tubing may be purged using the following project-specific requirements. The intake of the dedicated pump or tubing should be placed in the middle of the screened interval or slightly above the middle of the screen. Initial pumping rate should not exceed 0.125 gal/min, and the water level in the well should be monitored during the purging process. If the measured drawdown in the well exceeds 0.3 feet, then the pump rate should be reduced to keep the drawdown less than 0.3 feet. A final water level will be measured and recorded on the Field Data Sheet prior to sample collection to document that the low-flow criteria (less than 0.3 foot drawdown) was met. If the drawdown cannot be kept less than 0.3 foot, then the conventional well purging technique should be used.

After the start of the low-flow purging process, purge water measurements of temperature, conductivity, pH, and turbidity will be taken at regular intervals from 3 to 5 minutes apart. Sample collection will begin as soon as these parameters stabilize and one pump/tubing volume has been removed; stabilization criteria for low-flow purging is the same as the conventional well purging (see Section 3.2.2).

At very poor yielding wells, the well may be purged dry. In this case it is assumed that all unrepresentative water has been removed and that sampling can proceed when sufficient recovery has occurred.

#### 4.2.2 Field Parameter Monitoring

The parameters temperature, conductivity, pH, and turbidity will be monitored throughout the well purging process. For wells that are pumped, probes to monitor temperature, conductivity, and pH will be immersed in a flow-through cell (GJO Procedure LQ-10[P]) during purging. If a pump is not used for purging the well, measurement of temperature, conductivity, and pH will be made in an open container. Turbidity will be measured with a portable turbidity meter which requires a sample to be obtained from the pump/flow cell discharge or from the bailer.

The calibration and quality control (QC) procedures for field measurements obtained for ground-water stabilization criteria are presented in Table 4.2.2-1. The criteria defining field parameter stability have been revised from GJO Procedure LQ-3[P] as follows: stability is indicated when turbidity is  $\leq 5$  nephelometric turbidity units (NTUs), pH is within  $\pm 0.3$  pH units, and conductivity and temperature are each within  $\pm 10$  percent of the most current three consecutive readings. For conventional purging, a minimum of one reading will be recorded for approximately every one-sixth borehole volume evacuated. Sample collection may commence after one borehole volume is purged and stability criteria are met. For low-flow purging, parameter measurements will be made at the start of purging and every 3 to 5 minutes, until stabilization occurs. If a well is purged dry, all stagnant water is assumed to have been removed from the well, and sampling can occur when sufficient recovery has occurred (sample collection from slow recovering wells is discussed below). Alkalinity will be measured in the field after well purging criteria have been met.

If the 5 NTU criteria cannot be attained and proper well construction and development have been demonstrated, sampling will commence and the results will be evaluated with consideration of sample turbidity.

Procedures for the field measurement of pH, conductivity, alkalinity, temperature, and turbidity are presented in Appendix A (GJO Procedures LQ-4[T], LQ-5[T], LQ-7[T], LQ-8[T], and LQ-24[T], respectively). The standard solutions used for calibration and operational checks on the field instrumentation will be brought to within 10 degrees centigrade ( $^{\circ}\text{C}$ ) of the temperature of the purged water. A three-point check will be performed on the conductivity probe at the start and end of each sampling day. The pH meter will be calibrated before taking measurements at each well, and the conductivity and turbidity measuring devices will be operationally checked before taking measurements at each well. Any deviations from these measurements or instrument failures that can not be corrected prior to sample collection will be documented as a field variance in the field logbook (reference Section 4.5.6, Nonconformance and Corrective Action Procedure).

In addition to the parameters listed above, Eh and dissolved oxygen (DO) will be measured at all ground water sampling locations where well purging is accomplished with a pump. The Eh and DO measurements will be taken according the procedures presented in Appendix A (GJO Procedure LQ-6[T] and LQ-9[T], respectively) after purging and prior to sample collection.

Table 4.2.2-1 Calibration and QC Procedures for Well Purge Criteria

| Method   | Applicable Parameter | QC Check                             | Minimum Frequency                                   | Acceptance Criteria                                  | Corrective Actions                                                                                                                       | Data Flagging Criteria                          |
|----------|----------------------|--------------------------------------|-----------------------------------------------------|------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------|
| LQ-4(T)  | pH (water)           | 2 point calibration with pH buffers  | At each sample location before obtaining the sample | $\pm 0.3$ pH units                                   | If calibration is not achieved check meter, probe, and buffer solutions. Repeat calibration. If still out, flag data.                    | Record as a Field Variance in the field logbook |
| LQ-5(T)  | Conductance          | Calibrate with KCL standard          | At each sample location before obtaining the sample | $\pm 10\%$ most current three consecutive readings   | If calibration is not achieved check meter, probe, and standard. Repeat calibration. If still out, flag data.                            | Record as a Field Variance in the field logbook |
| LQ-8(T)  | Temperature          | None                                 | At each sample location before obtaining the sample | $\pm 10\%$ most current three consecutive readings   | Check meter and probe. Repeat measurement. If still out, flag data.                                                                      | Record as a Field Variance in the field logbook |
| LQ-24(T) | Turbidity            | Operationally check to NTU standards | At each sample location before obtaining the sample | $\leq 5$ NTUs most current three consecutive reading | Check meter, batteries, and standards. Wipe NTU standard container clean. Repeat measurements. If still out, repeat primary calibration. | Record as a Field Variance in the field logbook |

### 4.2.3 Purging Methods and Equipment

Well purging will be accomplished using a peristaltic pump, bladder pump, bailer, or submersible pump using Methods A, B, C, or D in the "Standard Practice for Purging of Monitoring Wells" (GJO Procedure LQ-3[P], Appendix A). Purging (and sampling) equipment is documented on the water sampling field data form for each well (Appendix A, GJO Procedure LQ-3[P]).

## 4.3 Sample Collection Methods

### 4.3.1 Ground Water

Sample fractions not requiring field filtration will be collected directly from the pump discharge line (not the flow-through cell discharge) or directly from the bailer, depending on the purge method. Bailed samples requiring field filtration will first be poured into an unused dummy sample bottle from which the sample will then be pumped by a peristaltic pump through an in-line filter to the sample bottle. Pumped samples will be filtered by directly affixing the filter to the discharge line outlet. Samples will be filtered through 0.45-micron ( $\mu\text{m}$ ) in-line disposable cartridge-type filters.

Standard collection procedures are described in "Standard Practice for the Collection, Filtration, and Preservation of Liquid Samples" (GJO Procedure LQ-12[P], Appendix A). Radon-222

samples will be collected with a bladder pump, bailer, or a submersible pump, as described in Methods B, C, or D, respectively of GJO Procedure LQ-12[P]. The remaining ground-water sample fractions may be collected by either peristaltic pump, bladder pump, bailer, or submersible pump, using Methods A, B, C, or D, respectively of GJO Procedure LQ-12[P].

Water samples collected for radon-222 analysis will be collected with no headspace or bubbles in the container. All other water sample containers will be filled to approximately 90 percent capacity. If the container overflows when being filled with the collected sample, the exterior of the container will be rinsed with distilled water and wiped dry before being packed for shipment.

Whenever full well recovery exceeds 2 hours, samples will be collected as soon as sufficient volume is available for a sample for each parameter. Care will be taken to pump wells slowly that have a low recharge rate. The slow pumping will minimize formation water cascading down the sides of the screen potentially resulting in accelerated loss of radon.

#### 4.3.2 Surface Water

Surface-water sampling locations will be approached from downstream to minimize the potential for introducing sediments into the sample from walking in the creek. Surface-water field measurements of pH, temperature, and conductivity will be taken in-situ; alkalinity will also be measured in the field. All surface-water samples except those requiring filtration, will be collected by container immersion by pointing the bottle mouth upstream (GJO Procedure LQ-11[P], Appendix A, Method G). Filtered samples will be collected with a peristaltic pump (Method A) with the pump intake submerged in the stream. Samples will be filtered through 0.45- $\mu$ m in-line disposable cartridge-type filters. Filtered samples will be collected for metals and radionuclides (except radon-222) analyses from all surface-water locations. Unfiltered samples will be collected for metals and radionuclide analyses from three locations: SW99-01, SW99-04, and SW92-06.

#### 4.4 Water Sampling Equipment

Table 4.4-1 lists equipment and supplies for ground-water sampling.

#### 4.5 Quality Control Samples

QC samples that will be collected in conjunction with water sampling include field duplicates and field equipment blanks. Refer to Table 4.5-1, Quality Control Sample Collection and Repeat Measurement Frequencies.

##### 4.5.1 Field Duplicates

Duplicate surface-water and ground-water samples will be collected in the field on a frequency of one duplicate sample per 20 water samples (or less) for each media and analytical parameter. Surface-water and ground water are considered separate media in the context of field duplicates. Duplicate water samples will be collected by alternately filling the original and duplicate sample container per analytical parameter. Duplicate samples will be submitted blind to the laboratory under a fictitious identity that is similar to the actual sampling locations.

Table 4.4–1 Water Sampling Equipment

|                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Turbidity Meter and Standards<br>HACH Alkalinity Kit<br>Flow Cells<br>YSI Water Quality Monitor (temperature, conductivity, Eh, and pH)<br>Electric Water-Level Indicator<br>Masterflex Peristaltic Sampling Pump (or equivalent)<br>Grundfos Redi-Flo2 Model Submersible Pump (with control box and tubing)<br>Purge Water Containers<br>Portable Generator<br>Compressor<br>QED Dedicated Bladder Pumps, Models T-1200 and T-1500<br>QED Bladder Pump Control Box<br>Teflon Bailers<br>Bailer Reel<br>Disposable Bailers<br>0.45-µm Pore-Size Disposable Filters<br>Sample Bottles<br>Conductivity Solution<br>Zobel Solution<br>Concentrated HCL, H <sub>2</sub> SO <sub>4</sub> , and HNO <sub>3</sub><br>pH Buffers (4, 7, and 10)<br>100, 1,000, 10,000 µmho/cm Conductivity Solutions<br>pH Paper<br>Pipette with Tips<br>Silicone Tubing<br>Buckets | Dissolved Oxygen Meter, Membrane kit, and Zero Check Solution<br>Deionized Water<br>Alconox<br>Absorbent Tissues<br>Custody Seals or Evidence Tape<br>Ice Chest with Blue Ice/Wet Ice (or equivalent)<br>Field logbook<br>Chain of Sample Custody Forms (form GJO 1512)<br>Material Safety Data Sheets (MSDSs)<br>Water Sampling Field Data Sheets<br>Ticket Book (with bar codes)<br>Well Completion Information<br>Calculator<br>Latex Gloves, Safety Glasses, Steel-Toed Boots, and Hard Hats<br>Squirt Bottles<br>Toolbox<br>Card Table<br>Gasoline<br>Well Keys<br>Waste Containers<br>Field Sampling Plan<br>Two-Way Radio<br>Plastic Sheeting<br>Flagging Tape<br>Clear Tape<br>Sample Labels |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Table 4.5–1 Quality Control Sample Collection and Repeat Measurement Frequencies

| Matrix                                     | Sample Type        | Frequency                   | Analysis                     |
|--------------------------------------------|--------------------|-----------------------------|------------------------------|
| Ground water                               | Field Duplicate    | 1 per 20 or fewer locations | Same as environmental sample |
| Surface water                              | Field Duplicate    | 1 per 20 or fewer locations | Same as environmental sample |
| Ground water/Surface Water                 | Equipment Blank    | 1 per 20 or fewer locations | Same as environmental sample |
| Ground-water–water level measurement       | Repeat measurement | 1 per 20 or fewer locations | Not Applicable               |
| Surface-water–Stream discharge measurement | Repeat measurement | 1 per 10 or fewer locations | Not Applicable               |

#### 4.5.2 Equipment Blanks

Equipment blanks provide a check for cross-contamination of samples by ineffective equipment decontamination. At a minimum, one equipment blank sample will be prepared in the field for every 20 water samples (or less) that are collected with non-dedicated equipment. Additional equipment blanks will be collected when circumstances warrant (i.e., change in decon source water or assigned personnel). Equipment blanks will be prepared by collecting a sample of the



final deionized rinse water (rinsate) used to decontaminate non-dedicated sampling equipment. Equipment blank samples will be submitted blind to the laboratory under a fictitious identity that is similar to the actual sampling locations.

## 4.6 Ground-Water Level Monitoring

For the data collection effort, ground-water levels will be measured in a total of 35 upgradient, Millsite, and downgradient monitoring wells. Table 4.6-1 summarizes the existing ground-water level monitoring network according to the formation in which the well is completed. The locations of the ground-water level monitoring wells are shown in Figures 2-1 and 2-2. Temporary and permanent well installations are proposed in the OU III IRA Work Plan (DOE 1999a). Figures showing the locations of new wells will be added to this Plan by issuing a program directive after their installation.

*Table 4.6-1 Ground-Water Level Measurement Network*

| General Location | Description                   | Well Number                                                                                                                           |
|------------------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|
| Upgradient       | Alluvial                      | 92-05                                                                                                                                 |
|                  | Burro Canyon                  | 92-06                                                                                                                                 |
|                  | Dakota Sandstone              | 92-13                                                                                                                                 |
| Millsite         | Alluvial                      | 82-20                                                                                                                                 |
|                  | Burro Canyon                  | 93-01, 31SW93-200-1                                                                                                                   |
|                  | Dakota Sandstone              | 31SW93-200-2                                                                                                                          |
|                  | Mancos Shale                  | 31SW93-200-3, 31SW93-200-4                                                                                                            |
| Downgradient     | Alluvial                      | 82-07, 82-08, 82-09, 88-85, 95-01, 95-03, 92-07*, 92-08, 92-09, 92-11, P92-01, P92-02, P92-03, P92-04, P92-05, P92-06, P92-07, P92-09 |
|                  | Burro Canyon                  | 95-02, 95-04, 95-06, 95-08, 92-10, 31NE93-205                                                                                         |
|                  | Burro Canyon/Dakota Sandstone | 83-70                                                                                                                                 |
|                  | Dakota Sandstone              | 92-12, 95-07                                                                                                                          |

\*Well 92-07 was damaged in June 1999. A water-level measurement will be attempted in July 1999 and discontinued thereafter.

As indicated in Table 4.6-1, the current monitoring well network consists of 19 wells completed in the alluvial system, 9 wells completed in the Burro Canyon Formation, 1 well completed in the Burro Canyon/Dakota Sandstone, 4 wells completed in the Dakota Sandstone, and 2 wells completed in the Mancos Shale.

Ground-water levels in the existing monitoring wells will be measured in January, April, July, and October every year to coincide with water quality monitoring and surface-water discharge measurement, which is described in the following section. Water levels in the temporary wells will be measured monthly for four months after their installation and then bi-monthly until major Millsite restoration activities necessitate their abandonment. Water levels in proposed permanent

wells will be monitored quarterly to coincide with water quality monitoring. The water-level measurement network will be periodically reviewed and updated. This may include adding or subtracting wells from the network and/or changing the measurement frequency.

For the PeRT wall treatability study effort, water levels in all PeRT wall performance monitoring wells listed in Table 3.2-1 will be measured during every sampling event. This water-level information will be used to determine ground-water flow directions through the reactive media and to monitor any ground-water mounding that may occur. In addition to the performance monitoring wells, water levels in 28 piezometers will be measured monthly through November 1999 and then quarterly beginning in January 2000. Water levels will be measured in slurry wall tracer test wells weekly in conjunction with sample collection during the duration of the slurry wall tracer test.

Repeat measurements for depth to water will be taken to verify method repeatability. Water level measurements will be repeated once for every 20 (or less) measurements.

Measurement of depth-to-water in monitoring wells will be made to the nearest 0.01-ft with an electric sounder as described in Method A in the "Standard Test Method for the Measurement of Water levels in Ground-Water Monitoring Wells" (GJO Procedure LQ-2[T], Appendix A). The document revision accompanying the procedure specifies the reference point on the well from which the depth measurements will be made.

The measured depth-to-water in the wells will be recorded in a hand-held electronic data entry device. Under certain field conditions, water level information may be recorded initially into the bound field logbook and transferred to the electronic data base at the earliest opportunity.

## **4.7 Monitoring Well Inspection**

Inspection of all monitoring wells listed in Table 4.6-1 will occur in conjunction with the scheduled sampling according to the procedures described in the "Standard Practice for the Inspection and Maintenance of Ground-Water Monitoring Wells" (GJO Procedure LQ-18[P], Appendix A). Well inspection information will be recorded in a hand-held electronic data entry device (GJO Procedure LQ-2[T], with document revision) or in the logbook as appropriate.

## **4.8 Surface-Water Discharge Monitoring**

### **4.8.1 Discharge Monitoring Locations**

Surface-water discharge will be quantitatively measured at 9 sites along Montezuma Creek. Discharge measurements will be taken at SW92-03 (on Montezuma Creek) located upstream of the Millsite. The discharge measurement site located on the Millsite is SW99-01. Discharge sites SW92-06, Sorenson, SW92-07, SW92-08, SW92-09, SW94-01, and SW99-04 are located downstream of the Millsite. The locations of the surface-water discharge monitoring sites are shown on Figure 2-1 and 2-2. Surface-water discharge will also be estimated at locations SW99-02 and SW99-03 on the Millsite.



#### 4.8.2 Discharge Monitoring Frequency

Surface-water discharge measurements will be taken in October, April, and July concurrent with water quality sampling and water level measurement activities. Discharge measurements will not be attempted in January because previous observations indicate that Montezuma Creek is mostly frozen during this time of year.

#### 4.8.3 Repeat Measurements

Repeat measurements for surface-water discharge will be taken to verify method repeatability. Surface-water discharge measurements will be repeated once for every ten (or less) locations.

#### 4.8.4 Method of Discharge Measurement

Due to the diffuse nature of flow at locations SW99-02 and SW99-03 on the Millsite, flow at these locations will be qualitatively estimated. Stream velocity and discharge at the other 9 measurement sites along Montezuma Creek will be determined according to the velocity-area method (GJO Procedure LQ-26[T] and LQ-27[T], Appendix A). Stream discharge will also be measured at locations on the Millsite where weirs are installed and may be measured at Millsite pond outlets (once constructed) if feasible.

The velocity-area method consists of measuring the representative current velocity in each of multiple partial cross-sections of stream flow. Total discharge at a given location is the sum of the area-velocity products of the individual sections.

The appropriate number of partial sections for velocity measurement is an arbitrary determination due to natural variability in channel shape, size, roughness, and velocity distribution. As a general guideline therefore, a frequency of one velocity measurement per 0.5-ft of stream width will be adopted, with the initial measurement taken 0.25-ft from the reference stream bank. At a minimum, the stream depth will be measured at the midpoint and two endpoints of each partial section, including the depth immediately adjacent to each bank. Stream width and depth measurements will be recorded to the nearest 0.1 ft and 0.025-ft, respectively.

Within each partial cross-section, the velocity will be measured at six-tenths the total depth relative to the upper surface, approximating the average velocity in typical stream depth-velocity profiles (LQ-27[T]). Within a 1-ft depth stream section, the velocity will therefore be measured at 0.6 ft below the water surface or 0.4-ft above the stream bed.

Stream velocity will be measured with a Swoffer Model 2100 Series Current Velocity Meter (rotating element type), or equivalent. Features of the Swoffer meter include the true depth and six-tenths index scales for rapid depth placement of the rotating element. Velocities will be determined from a 30-second velocity averaging period. Calibration and operation of the current meter will proceed according to the manufacturer's recommendations and the general guidelines described in LQ-26(T). Instrument calibration results will be documented in the field logbook. Additional information to be recorded by field personnel includes recent and current weather conditions, crop irrigation (location, point of withdrawal, number of sprinkler heads, etc.),

presence or absence of water in tributary streams, bank seepage, and other surface-water withdrawals or returns.

The accuracy of stream-discharge measurements by the velocity-area method is a function of meter accuracy, area and depth measurement accuracy, and representativeness of the measured velocity. To minimize the effects of natural variation on measurement accuracy, the following factors will be considered prior to measurement:

- Straight stream reaches are preferred.
- Uniform flow within a single, well-defined, smooth channel is preferred with no overbank or underbank flow.
- Avoid overhanging brush and submerged vegetation.
- Avoid irregular, rough stream bottoms.
- Avoid eddied, turbulent, and stagnant water.
- Observe rotating elements during velocity measurement to confirm proper operation.

Table 4.8.4-1 itemizes the equipment needs for measuring stream discharge.

*Table 4.8.4-1 Surface-Water Discharge Measurement Equipment*

|                                                                                                                                                                    |                                                                                             |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| Swoffer Current Meter (or equivalent) with operations manual and spare parts<br>Steel Tape (25 ft) or equivalent<br>Deionized Water<br>Alconox<br>Absorbent Tissue | Field Logbook<br>Squirt Bottles<br>Waste Containers<br>Field Sampling Plan<br>Two-Way Radio |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|

## 4.9 Equipment Decontamination Procedures

Non-dedicated water sampling equipment will be decontaminated prior to the collection of each sample. Decontamination will proceed according to Method B of the "Standard Practice for Equipment Decontamination" (GJO Procedure GT-7[P], Appendix A).

Decontamination water from ground-water sampling sites will be managed with purge water, as described in Section 3.2.1. Decontamination water at surface-water sites will be released at the stream side. Decontaminated equipment will be wiped dry with clean absorbent tissue and placed in clean protective containers or plastic bags until further use.

#### 4.10 Investigation Derived Waste

All excess water generated during ground-water sampling activities (purge water and decontamination water) will be managed as described in Section 4.2.1.

Trash generated during all sampling/measurement tasks will be disposed in trash receptacles located within the DOE property boundaries.

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## 5.0 Sample Management and Sample Analysis

### 5.1 Sample Containers, Preservation, and Holding Times

Table 5.1–1 summarizes the containers, preservation, holding times, and analytical parameters, for water samples collected under this plan.

*Table 5.1–1 Sample Containers, Preservation, Holding Times, and Analytical Parameters for OU III Water Samples*

| Analytical Parameter                                                       | Container Type/Size <sup>a</sup>         | Preservation                                                                               | Holding Time |
|----------------------------------------------------------------------------|------------------------------------------|--------------------------------------------------------------------------------------------|--------------|
| Metals (As, Co, Cu, Fe, Mn, Mo, Pb, Se, Th-230, U, V, Zn) <sup>b, c</sup>  | HDPE <sup>d</sup> /500mL Amber           | Filter by 0.45- $\mu$ m filter<br>HNO <sub>3</sub> to pH<2                                 | 6 Months     |
| Major Cations (Ca, Mg, K, and Na)<br>(same bottles as metals)              | HDPE                                     |                                                                                            |              |
| Major Anions (Cl, F, HCO <sub>3</sub> <sup>-</sup> , and SO <sub>4</sub> ) | HDPE/125 mL                              | Filter by 0.45- $\mu$ m filter;<br>Cool to 4 °C                                            | 28 Days      |
| Bromide                                                                    | HDPE/125 mL                              | Cool to 4 °C                                                                               | 28 Days      |
| Nitrate (NO <sub>3</sub> + NO <sub>2</sub> as N)                           | HDPE/125 mL                              | Filter by 0.45- $\mu$ m filter;<br>Cool to 4 °C; H <sub>2</sub> SO <sub>4</sub> to<br>pH<2 | 28 Days      |
| Total Dissolved Solids (filterable<br>residue)                             | HDPE/125 mL                              | Cool to 4 °C                                                                               | 7 Days       |
| Gross Alpha/Gross Beta <sup>e</sup>                                        | HDPE/1 L <sup>e</sup>                    | Filter by 0.45- $\mu$ m filter;<br>HNO <sub>3</sub> to pH<2                                | 6 Months     |
| Lead-210 <sup>f</sup>                                                      | HDPE/3 L                                 | Filter by 0.45- $\mu$ m filter;<br>HNO <sub>3</sub> to pH<2                                | 6 Months     |
| Radium-226 <sup>f</sup>                                                    | HDPE/1 L                                 | Filter by 0.45- $\mu$ m filter;<br>HNO <sub>3</sub> to pH<2                                | 6 Months     |
| Radon-222                                                                  | Amber Glass w/Teflon<br>Septa/ 3 @ 40 mL | Cool to 4 °C                                                                               | Not Estab.   |
| U-234, and U-238 <sup>g</sup> (from same bottle<br>as metals)              | HDPE                                     | Filter by 0.45- $\mu$ m filter;<br>HNO <sub>3</sub> to pH<2                                | 6 Months     |

<sup>a</sup>Sample volumes may vary according to laboratory requirements.

<sup>b</sup>Metal analytes for PeRT wall performance monitoring samples are As, Fe, Mn, Mo, Se, Th-230, U, and V.

<sup>c</sup>At locations SW99–01, SW99–04, and SW92–06 unfiltered samples will also be collected for metals and radionuclide analyses.

<sup>d</sup>HDPE = high-density polyethylene

<sup>e</sup>Two samples collected at locations where analysis by separate methods is designated; see Section 5.2.

<sup>f</sup>Isotopic uranium analysis will be conducted on water samples from bedrock and 95-series alluvial wells only.

All bottles used will be new and pre-cleaned according to EPA protocol in *Specifications and Guidance for Contaminant-Free Sample Containers* (EPA 1992). Suppliers will provide certificates of analysis as verification of bottle cleanliness. Bottles will be visually inspected for integrity and cleanliness before use. Suspect containers will not be used and will be discarded.

Sample fractions that require cooling will be placed in a cooler after collection and maintained at temperatures between  $>0^{\circ}\text{C}$  and  $4^{\circ}\text{C}$  until laboratory analysis. The cooler will be checked for the presence of ice and replenished if necessary, following final collection and storing of samples at each site, and prior to shipment. Cooler temperatures will be measured at the laboratory upon receipt.

Preservation of some water sample fractions requires addition of specific acids to achieve a desired pH. Following the acidification of the appropriate samples, the required pH will be confirmed on a frequency of one pH measurement per acid type, per bottle size, per sample. A small amount of sample will be poured from a sample container onto pH indicator paper to prevent contamination of the sample. Acid preservation (or other required chemical preservative) will occur as soon as possible after sample collection. Preservative may be added to bottles prior to sample collection if practical.

If chemical preservation cannot be accomplished at the sampling site, samples will be maintained at temperatures between  $0^{\circ}\text{C}$  and  $4^{\circ}\text{C}$  until preservation can occur. Unless prior approval is obtained, preservation will occur on the same day as sample collection and prior to sample shipment.

## 5.2 Analytical Program

Chemical analysis of water samples will be performed by the Grand Junction Office (GJO) Analytical Chemistry Laboratory. The analytical method and method detection limit for each analyte are shown in Table 5.2-1. Because high total dissolved solids negatively influences the detection of gross alpha and gross beta, a coprecipitation method in addition to GJO's Analytical Chemistry Laboratory standard evaporation method will be used for analysis of all upgradient samples and Mancos and Dakota bedrock ground-water samples collected. These locations typically have total dissolved solids concentrations exceeding 500 mg/L and low to nondetectable concentrations of gross alpha. The coprecipitation method involves use of barium sulfate, and iron hydroxide to precipitate alpha emitting (and probably beta emitting) radionuclides from the sample's dissolved solids. Alluvial aquifer samples downgradient of the Millsite need not be submitted for analysis by coprecipitation because gross alpha and gross beta are significantly elevated in the alluvial system in this area (i.e., there is no detection limit problem). Burro Canyon aquifer samples will not be submitted for analysis by coprecipitation because total dissolved solids concentrations are typically low in these samples. Instead, gross alpha and beta samples from these locations will be analyzed by the standard evaporation method. The specific analytical method will be indicated on the sample ticket form (see Section 5.2).

## 5.3 Sample Handling, Packaging, and Shipping

Unused sampling equipment, sample containers, and coolers that have been shipped or transported to the site or a sampling location will be kept in clean, secure location to minimize damage, tampering, and possible contamination.

Table 5.2-1 Laboratory Reporting Limits and Analytical Methods for OU III Water Samples

| Analytical Parameter                             | Method Detection Limit <sup>a</sup> | Analytical Method <sup>b</sup>                   |
|--------------------------------------------------|-------------------------------------|--------------------------------------------------|
| <b>Metals</b>                                    | (µg/L)                              |                                                  |
| Arsenic                                          | 1.0                                 | EPA SW-846 7062 (Hydride-AA)                     |
| Cobalt                                           | 1.0                                 | EPA SW-846 6020 (ICP-MS)                         |
| Copper                                           | 5.0                                 | EPA SW-846 6020 (ICP-MS)                         |
| Iron                                             | 50.0                                | EPA SW-846 6020 (Radial ICP-AES)                 |
| Lead                                             | 1.0                                 | EPA SW-846 6020 (ICP-MS)                         |
| Manganese                                        | 1.0                                 | CLP Method 200.7 (Radial ICP-AES)                |
| Molybdenum                                       | 3.0                                 | EPA SW-846 6020 (ICP-MS)                         |
| Selenium                                         | 1.0                                 | EPA SW-846 7742 (Hydride-AA)                     |
| Thorium-230                                      | 1.0                                 | EPA SW-846 6020 (ICP-MS)                         |
| Uranium                                          | 1.0                                 | EPA SW-846 6020 (ICP-MS)                         |
| U-234, U-238 <sup>c</sup>                        | 1.0                                 | EPA SW-846 6020 (ICP-MS)                         |
| Vanadium                                         | 2.0                                 | CLP Method 200.7 (Radial ICP-AES)                |
| Zinc                                             | 15.0                                | CLP Method 200.7 (Radial ICP-AES)                |
| <b>Total Dissolved Solids</b>                    | 10,000                              | EPA Method 160.1                                 |
| <b>Major Anions</b>                              |                                     |                                                  |
| Chloride                                         | 5                                   | EPA Method 300                                   |
| Sulfate                                          | 50                                  |                                                  |
| Fluoride                                         | 5                                   |                                                  |
| Nitrate (NO <sub>3</sub> + NO <sub>2</sub> as N) | 5                                   |                                                  |
| Bromide                                          | 8                                   |                                                  |
| <b>Major Cations</b>                             |                                     |                                                  |
| Calcium                                          | 10                                  | CLP Method 200.7 (Radial ICP-AES)                |
| Magnesium                                        | 20                                  |                                                  |
| Potassium                                        | 100                                 |                                                  |
| Sodium                                           | 50                                  |                                                  |
| <b>Radionuclides</b>                             | (pCi/L)                             |                                                  |
| Lead-210                                         | 2.0                                 | GJO Method RC-6                                  |
| Radium-226                                       | 1.0                                 | GJO Method RC-5                                  |
| Radon-222                                        | 20.0                                | GJO Method RC-17                                 |
| Gross Alpha Activity                             | 1.0; TBD <sup>d</sup>               | GJO Method RC-3 and Method 00-02-01 <sup>e</sup> |
| Gross Beta Activity                              | 1.0; TBD                            | GJO Method RC-3 and Method 00-02-01              |

<sup>a</sup>µg/L = micrograms per liter; pCi/L = picocurie per liter.

<sup>b</sup>GJO laboratory methods listed in the absence of existing EPA methods.

<sup>c</sup>Isotopic uranium analyses will be conducted on water samples collected from bedrock and 95-series alluvial wells only.

<sup>d</sup>TBD = To be determined.

<sup>e</sup>Method 00-02-01 (EPA 1984) is a method for determining gross alpha in drinking water using coprecipitation; although the method specifically addresses gross alpha, beta emitting isotopes will also probably precipitate. See Section 5.2 for method and sample location information.

Sample containers will be securely packaged to protect the contents from damage, spilling, leaking, or breaking during transport between sampling and laboratory destinations. Samples in glass containers will be placed in plastic bags and wrapped in bubblewrap or otherwise appropriately contained (slotted foam) to protect the sample container during shipment. Void space in shipping containers may be filled with an inert material or additional ice, if appropriate, to further protect and secure the contents.

All samples will be handled, packaged, and shipped as environmental samples. Based on the results of prior sampling and analysis, surface-water and ground-water samples collected from



the study area do not qualify as "Radioactive Material," and therefore do not need to be handled, packaged, labeled, and shipped as Radioactive Material according to *MACTEC-ERS General Administrative Procedure Manual*, Section 9.0, "Transportation of Radioactive Hazardous Materials" (MAC-1000, 1996).

On arrival to the laboratory, the sample coordinator (recipient) must examine the shipping containers and document the receiving condition, including integrity of custody seals, when applicable. When opening the shipping container the sample coordinator will examine the contents and record the condition of the individual sample containers (e.g., bottles broken or leaking), the temperature of the water bath (when applicable), temperature or condition of frozen samples (when applicable), method of shipment, courier name(s), and other information relevant to sample receipt and log-in. The individual receiving the samples verifies that the information on the sample container(s) matches the information on the Chain of Sample Custody form prior to signing the Custody form.

## 5.4 Sample Custody

To ensure the integrity of the sample, the Field Supervisor or their designee, is responsible for the care, packaging, and custody of the samples until they are dispatched to the laboratory. The procedures described in "Standard Practice for Chain-of-Sample-Custody Control and Physical Security of Samples" (GJO Procedure GT-3[P], Appendix A) will be implemented to provide security and document sample custody.

Custody seals and/or evidence tape will be placed on each ice chest or storage/shipping container that is not in direct control of a sampling team member to maintain physical security of the samples from time of collection to analysis. Samples not in direct control of a sampling team member will be stored in a secured (locked) location. Ice chests, cartons, and trays used for temporary sample storage that are not custody sealed must be in direct control of a field team member.

If samples are transported by subcontract employees or commercial carrier, the shipping container will have custody seals and/or evidence tape placed over the container opening before shipment to ensure that the integrity of the samples is not compromised during transportation. Custody seals are not required for containers or samples that are transported by contractor personnel directly to the GJO Analytical Chemistry Laboratory for analysis. Mailed sample packages should be registered with return receipt requested. If packages are sent by common carrier, receipts are retained as part of the chain-of-custody documentation. Other commercial carrier documents shall be maintained with the chain-of-custody records.

Chain-of-custody records will be used to list all transfers in the possession of the samples and to show that the samples were in constant custody between collection and analysis. Samples that are sent or transported to an analytical laboratory by individuals other than a member of the field sampling team will be accompanied by a Chain of Sample Custody form (GJO 1512) or equivalent, with a copy retained by the originator. When samples are transported to the GJO Analytical Chemistry Laboratory by a member of the field sampling team, the Chain of Sample Custody form may be completed at the sample receiving facility when the transfer is made.

## 5.5 Documentation and Document Control

All entries in field logbooks, data sheets, and sample labels and on forms will be made with indelible (waterproof) ink and will be legible, reproducible, accurate, complete, and traceable to the sample measurements and/or site location and in a manner consistent with the procedure described in "Standard Practice for Field Documentation Processes" (GJO Procedure GT-1[P], Appendix A). These documents will be retained as project records. These documents are intended to provide sufficient data and observations to enable participants to reconstruct events that occurred during the field sampling activities. Field logbooks and forms (sample ticket books, sample collection data sheets, field measurements data forms, sample container certificates of cleanliness, custody forms, shipping forms, etc.) will be stored in a manner that protects them from loss or damage. The Field Supervisors will be the custodians of all records for the duration of field activities. At the conclusion of a field task or sampling event, the field and data collection activities will be reviewed and summarized in a report to the Project Coordinator.

When practical, correction of errors should be made by the individual who made the entry. Errors will be corrected by drawing a line through the error, entering the correct information, then initialing and dating the entry. The erroneous material must not be obliterated.

When a document requires replacement because of illegibility or inaccuracies, the document will be voided and a replacement document will be prepared. A notation will be made on the voided document that a replacement document was completed. The voided document will be retained with the field documentation. The following sections describe the various documents that will be controlled and procedures for field variance reporting.

### 5.5.1 Field Logbook

Field personnel will use bound logbooks with consecutively numbered pages as field logbooks for each major task performed. The field logbooks will be used to record the daily activities of the field team, record sketch maps of sampling sites, etc., and sample locations, times, and identifications. Observations of conditions that may impact data quality or interpretation will also be noted. Each page will be signed and dated by the person making the entries on that page and by the Field Supervisor after review. An initial's log will be established at the beginning of the logbook to identify personnel authorized to record and/or review and authenticate field data. Any visitors to the site (DOE, EPA, State) will be noted, as well as their arrival and departure times and general activities (auditing, observing, etc.)

### 5.5.2 Sample Ticket Books

Preprinted sample ticket books with unique, sequential 6-digit ticket numbers will be assigned at the beginning of each sampling event. All pertinent information recorded on each sample container label (including the project, sampler, date and time of collection, and sample location ID) also will be recorded in the sample ticket book. Information such as unusual sampling conditions or other observations also may be recorded. A self-adhesive decal, printed and bar coded with the sample ticket number, will be removed from the sample ticket and affixed to the sample container label. The sample ticket books will serve as a field sample catalog and provide traceability of analytical data to sample locations.

### 5.5.3 Chain of Custody Form

The custody of individual sample containers will be documented by recording each container's identification and matrix on a Chain of Sample Custody form, in accordance with the requirements specified in "Standard Practice for Chain-of-Sample-Custody Control and Physical Security of Samples" (GJO Procedure GT-3[P], Appendix A).

These forms will be used to list all transfers of sample possession and will provide the GJO Analytical Chemistry Laboratory with the types of analysis to be performed to the samples. These forms will become part of the permanent project file upon completion of fieldwork. Copies of the form received by the laboratory and the subcontracted facilities will be included in the final analytical report.

### 5.5.4 Water-Sampling Field Data Form

A Water-Sampling Field Data Form will be used to record and document sample collection and identification information, purge volume calculations, indicator parameter measurements, purge and sampling equipment, and instrument calibration information. An example form is included in GJO Procedure LQ-3(P), Appendix A. A copy of the completed forms will be submitted to the GJO Analytical Chemistry Laboratory for inclusion in the final analytical report.

### 5.5.5 Nonconformance and Corrective Action Procedure

Deviations from specified field protocols and/or sampling procedures established in planning documents or Standard Operating Procedures must be authorized by the Project Manager and fully documented by the Field Supervisor. Field variances will be reported in a timely manner for evaluation of impact to the data. Field variance reporting applies to deviations to (1) prescribed field sampling, measurement, or survey techniques; (2) specified shipping handling or storage requirements; and (3) decontamination procedures. A field logbook entry must be made whenever an activity is performed or sample is obtained that does not fall within the methods or protocols specified for sample, measurement or survey techniques, use of an instrument that is out of calibration or has failed and operational check, loss of traceability of sample, measurement or survey data to their location, noncompliance with established procedures, and/or loss of or damage to records that can not be duplicated.

The variance should be fully described (including an accurate reference to the document and section within the document that the activity varied), as well as the immediate corrective action taken, if applicable. Comments describing the variance will be used during sample processing and data evaluation to assess the use of associated results and validity of the data. For reference purposes, a table of contents for field variances will be established at the beginning of the logbook and will include the page number and a brief descriptive title for all field variance information that is documented in the logbook.

Field variances that may result in a nonconformance due to unacceptable or indeterminate sample or data quality, will be reported to the Quality Assurance (QA) Coordinator by the Project Manager. If corrective action is required, the field variance will be reported as a nonconformance. Proposed corrective action will be approved by the Project Manager and will



## **Appendix A**

### **Field Sampling Procedures**

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## Environmental Procedures Catalog Document Addition/Revision

**Procedure Title:** Standard Test Method for the Measurement of Water Levels in Groundwater Monitoring Wells, [LQ-2(T)], Rev. 2, 11/92

**Requester:** Tim Bartlett, Field Supervisor

**Justification:** (1) To better define the measuring point location on the well casing. (2) Actions to meet the instrument check requirements are defined. (3) Time will not be recorded because it is not relevant.

**Proposed Change:** Section 1.1 - If the casing is not marked with a measurement reference point, and the casing is not cut horizontal, measurements will be made from the high point of the casing. If the casing is not marked with a measurement reference point and the casing is cut horizontally, measurement will be made from the north side of the casing. Section 8 - Instruments will be checked with a steel tape on an annual basis as a minimum. When performed, the check will be recorded in the field logbook. Section 16.1.1 - Time will not be recorded. Water-level measurements will be entered into an electronic hand-held data entry device and/or field data book.

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### Authorization for Changes to Catalog Procedures

☐ New Document

☐ Change to Existing Procedure

☐ Adopt Procedure

Procedure Number Assigned \_\_\_\_\_

Procedure Title \_\_\_\_\_

Approval for Inclusion in Environmental Procedures Catalog:

\_\_\_\_\_  
Environmental Procedures Advisory Committee Chair

\_\_\_\_\_  
Date

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### Authorization for Project Specific Modification to Existing Catalog Procedures

Project Specific Change for MMTS Operable Unit III, Interim Remedial Action Surface Water and Ground Water Monitoring Program (MAC-MSGRAP 1.3.5-2)

Effective Date April 5, 1999

Reviewed By *D. Miller*  
Technical Author or  
Proficient Designee

4/1/99  
Date

Approved By *Krista McCallum*  
Manager or Designee

4/1/99  
Date

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# Standard Test Method for the Measurement of Water Levels in Groundwater Monitoring Wells

## Introduction

Water-level measurements shall be taken prior to any sampling or well purging. These measurements are needed to determine the casing volume of water in the well; the data are used to interpret the monitoring results. High water levels could indicate recent recharge to the system, which would dilute the sample. Low water levels could reflect the influence of nearby production wells. Documentation of nonpumping water levels also provides historical information on the hydraulic conditions at the site (see reference 3.7).

## 1. Scope

1.1 Water levels shall be measured from the top of the well casing and, for consistency, shall always be made from the same spot on the well casing. If the planning documents do not specify a reference point, and other reference points do not exist, the measurement shall be made on the north side of the well casing.

1.2 Three methods are provided in this test method for water-level measurement.

1.2.1 The first method uses an electric water-level sounder with a conductivity cell. When the cell contacts water, it completes an electrical circuit, activating an audio and/or visual alarm.

1.2.2 The second method uses an interface probe. This instrument has an optical liquid sensor and a conductivity cell and can distinguish between the presence of a nonconductive layer and a conductive layer. For example, oils, fuels, and many organics are nonconductive and are immiscible with water. With an interface probe, the sampler can measure the thickness of a light non-aqueous-phase liquid (LNAPL) layer, which floats on the water's surface, or a dense non-aqueous-phase liquid (DNAPL) layer, which sinks to the bottom of the well.

1.2.3 The third method uses an electronic/pneumatic water-level meter in conjunction with a dedicated water-level probe. The water-level meter measures the pressure it takes to force the water out of the dedicated water-level probe and converts that pressure to the submersion depth of the probe. This depth is then subtracted from the total probe length (obtained during installation), giving the depth to water.

## Section

Method A — Water-Level Measurements Using an Electric Sounder

6-8

Method B — Water-Level Measurements Using an Interface Probe

9-11

Method C — Water-Level Measurements Using a Well Wizard Model 6010E Electronic/Pneumatic Water-Level Meter with a Dedicated Water-Level Probe

12-15

## 2. Hazard Analysis

2.1 Site-specific controls (e.g., radiological controls in a contaminated area, respirators, personal protective equipment, and decontamination) are available in the planning documents, such as the Health and Safety Plan, for a particular project. These documents should be consulted before beginning work on a project.

2.2 This test method uses methanol for decontaminating the apparatus. Methanol is a Department of Transportation (DOT)-regulated material; its hazard class is Flammable Liquid. Methanol has an Occupational and Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL)-Time-Weighted Average (TWA) of 200 parts per million (ppm) and a PEL-Short Term Exposure Limit (STEL) of 250 ppm (see reference 3.2). Methanol can also potentially enter the body through the skin.

2.2.1 Some of the effects of methanol by inhalation or skin absorption include dizziness, nausea, weakness, shooting pain in the arms or legs, gastric pain, blurred vision, changes in color perception, double vision, and blindness (see reference 3.3).

2.2.2 Avoid eye and skin contact by wearing eye protection and nitrile (including thin Best

N-Dex), butyl, or neoprene gloves. Avoid breathing vapors by using only in a well-ventilated area. Keep away from heat, sparks, and flames.

2.3 Method C involves use of an air compressor to charge the internal tank of the water-level meter. Safety precautions include:

2.3.1 Air compressors that are belt-driven shall have a belt guard in place.

2.3.2 Air compressors shall not be operated above the rated capacities and shall be configured to avoid having any dead-end fittings above 20 pounds per square inch (psi). Carefully check for loose connections before operating.

2.3.3 Use proper lifting techniques when lifting air compressors.

2.3.4 Ensure that the air compressor is equipped with an over-pressure relief valve and regulator.

2.3.5 The air compressors used for Method C are gasoline-powered.

2.3.5.1 Gasoline is a DOT-regulated material; its hazard class is Flammable Liquid. Gasoline has an OSHA PEL-TWA of 300 ppm and a PEL-STEL of 500 ppm (see reference 3.2).

2.3.5.2 Avoid eye and skin contact by wearing eye protection and nitrile or butyl gloves. Avoid breathing vapors by using only in a well-ventilated area. Keep away from heat, sparks, and flames.

2.3.5.3 Some of the symptoms of gasoline exposure include dizziness, intoxication, blurred vision, headache, skin irritation, and flushed facial skin tone (see reference 3.3).

2.3.5.4 Gasoline shall be stored in Factory Mutual-approved safety cans. Safety cans shall be well secured in the vehicle during transport. Gasoline-powered compressors must be cool before filling, and care shall be taken to avoid spilling any gasoline.

2.3.5.5 A 10-pound dry chemical fire extinguisher should be available when fueling the compressor.

### 3. Referenced Documents

3.1 *American Society for Testing and Materials, 1990 Annual Book of ASTM Standards, Section 11, "Water and Environmental Technology," Vol. 11.04, Pesticides; Resource Recovery;*

*Hazardous Substances and Oil Spill Responses; Waste Disposal; Biological Effects:*

ASTM D 4448-85a—Standard Guide for Sampling Groundwater Monitoring Wells.

3.2 *Code of Federal Regulations (CFR), Title 29, "Labor":*

29 CFR 1910, Occupational Safety and Health Standards.

3.3 Micromedex, Inc., *TOMES Plus*, CD-ROM Database, Vol. 13, Chicago, IL, 1992.

3.4 QED Environmental Systems, Inc. *Well Wizard Model 6010E Electronic/Pneumatic Water Level Meter Installation and Operation Instructions*. Ann Arbor, MI, 1991.

3.5 U.S. Department of Energy, *The Environmental Survey Manual*, Appendix E, "Field Sampling Protocols and Guidance," Office of the Assistant Secretary, Environment, Safety and Health, Vol. 4, DOE/EH-0053, 1987.

3.6 U.S. Environmental Protection Agency, *Handbook of Groundwater*, EPA/625/6-87/016, 1987.

3.7 U.S. Environmental Protection Agency, *Practical Guide for Groundwater Sampling*, EPA/600/2-85/104, 1985.

### 4. Terminology

4.1 *Conductivity cell*—A simple electrical circuit that, when completed, causes electrical current to flow.

4.2 *Dedicated water-level probe*—A stainless steel probe permanently attached with polyethylene tubing to the cap of a well and used to obtain water-level information.

4.3 *Electric water-level sounder*—An electronic probe that uses a conductivity cell to activate an alarm when it contacts a conductive liquid.

4.4 *Electronic/pneumatic water-level meter*—A device that uses an internal compressed air source (pneumatic) to force air down the dedicated water-level probe. The meter senses the amount of pressure needed to push the water out of the dedicated water-level probe using a pressure transducer and associated circuitry and software (electronic). The meter converts this pressure to the depth of submersion of the probe.

4.5 *Interface probe*—A probe designed to detect conductive and nonconductive layers in a well.

4.6 *Monitoring well*—A well installed for the purposes of obtaining water quality data, hydrogeologic information, and/or water-level data.

## 5. Significance and Use

5.1 Accurate measurements of water depth are necessary in the calculation of well bore volumes; measurements to the nearest 0.01 foot (ft) are routine.

### Method A Water-Level Measurements Using an Electric Sounder

## 6. Apparatus

6.1 Electric sounder. (There are many adequate electric sounders available. This procedure covers most models.)

6.2 Kimwipes or equivalent lint-free tissue.

6.3 Distilled or deionized water in a squeeze wash bottle.

6.4 Measuring tape with an engineering scale.

## 7. Procedure

7.1 The following procedure is supplemental to the instruction found in the instrument-specific operating manual:

7.1.1 Check the sounder to ensure the batteries are charged.

7.1.2 Clean the probe of the sounder with distilled or deionized water and wipe dry with a lint-free tissue.

7.1.3 Slowly lower the probe into the well until the indicator sounds.

7.1.4 Raise the probe slightly until the indicator stops sounding.

7.1.5 Carefully lower the probe until the indicator sounds again and read the depth to water to the nearest 0.01 ft, using a measuring tape with an engineering scale if necessary.

7.1.6 Repeat steps 7.1.4 and 7.1.5 until a repeatable measurement is achieved.

7.1.7 Record the depth to water to the nearest 0.01 ft.

7.1.8 Slowly withdraw the probe from the well while wiping the cable with a lint-free tissue moistened with distilled or deionized water.

7.1.9 Clean the probe with distilled or deionized water and wipe dry with a lint-free tissue.

## 8. Procedure Bias

8.1 With this method, water-level measurements must be repeatable to  $\pm 0.01$  ft. The accuracy of the probe shall be routinely checked against a steel measuring tape to ensure that the cable has not stretched or twisted.

### Method B Water-Level Measurements Using an Interface Probe

## 9. Apparatus

9.1 Soiltest Model 447-000 Interface Probe or equivalent.

9.2 Kimwipes or equivalent lint-free tissue.

9.3 Distilled or deionized water in a squeeze wash bottle.

9.4 Methanol

## 10. Procedure

10.1 The following procedure is supplemental to the instruction found in the instrument-specific operating manual:

10.1.1 Clean the probe with methanol, followed by a distilled or deionized water rinse, and wipe dry with a lint-free tissue.

10.1.2 Check the battery level and replace if low.

10.1.3 Slowly lower the probe into the well until the probe comes in contact with liquid. A steady audible alarm indicates an immiscible, non-conductive liquid, while an oscillating alarm indicates a conductive liquid (water).

10.1.4 When the alarm sounds, raise the probe slightly until the alarm stops. Carefully lower until the alarm sounds again and note the depth. Repeat as necessary until a repeatable measurement of  $\pm 0.01$  ft is achieved. Record this measurement.



10.1.5 If a LNAPL layer is present as indicated by a steady audible alarm, the thickness can be measured by recording the point at which the steady alarm begins and the point at which the oscillating alarm begins. The difference between the two measurements is the thickness of the LNAPL layer.

10.1.6 If a DNAPL layer is suspected, it can be measured by slowly lowering the probe to the bottom of the well. If a DNAPL layer is present, the thickness can be measured by recording the difference between the point at which the steady alarm begins and the point at which the probe reaches the bottom of the well.

10.1.7 Carefully withdraw the probe from the well while wiping the cable with a lint-free tissue moistened with distilled or deionized water. If the well contained any LNAPL layers, the cable shall be rinsed with methanol followed by a distilled or deionized water rinse and wiped dry with a lint-free tissue as it is being removed from the well.

10.1.8 Clean the probe with methanol, followed by a distilled or deionized water rinse, and dry with a lint-free tissue.

## 11. Procedure Bias

11.1 When using the interface probe for liquid level measurements, readings of  $\pm 0.01$  ft can be achieved. The accuracy shall be routinely checked using a steel measuring tape to determine if the cable has stretched or twisted.

### Method C Water-Level Measurements Using a Well Wizard Model 6010E Electronic/Pneumatic Water-Level Meter with a Dedicated Water-Level Probe

## 12. Apparatus

12.1 Well Wizard Model 6010E electronic/pneumatic water-level meter.

12.2 Well Wizard Model 6111 stainless steel water-level probe and associated polyethylene tubing, fittings, and cap assembly.

12.3 Well Wizard Model 6015 calibration assembly.

12.4 Well Wizard 41000 series oil-free compressor or equivalent.

## 13. Procedure

13.1 The following procedure is supplemental to the instruction found in the instrument-specific operating manual (see reference 3.4):

13.1.1 Rapid temperature changes will adversely affect the water-level meter operation. The meter must equilibrate to ambient temperature conditions for a minimum of 45 minutes before use.

13.1.2 Charge the internal tank of the water-level meter to 100 psi by attaching an oil-free air supply to the fitting marked "TANK RECHARGE."

13.1.3 Move the "SENSOR" switch to the "ON" position.

13.1.4 Wait for the liquid crystal display (LCD) message to read "ATTACH TO WELL."

13.1.5 Attach the meter air tubing from the water-level meter fitting marked "TO AIR PROBE" to the white air fitting on the well cap.

13.1.6 Move the "AIR" switch forward to the "ON" position.

13.1.7 Press the "START" button once.

13.1.8 Press the "AIR PRECHARGE" until the LCD display shows the highest reading.

13.1.9 Leave the "AIR" switch in the "ON" position. The LCD message will read "PROBE SUBMERSION DEPTH B," and the reading shall be recorded when the depth stabilizes.

13.1.10 Move the "AIR" and "SENSOR" switches back to the "OFF" position.

13.1.11 To determine the depth to water, subtract the probe submersion depth from the probe length determined during installation.

13.1.12 When the batteries begin to get low, the LCD message will read "WARNING! LOW BATTERIES" after pressing the "START" button. Pressing the "START" button again will allow additional limited use, but the batteries must be replaced soon.

13.1.13 If the LCD message reads "BATTERY TOO LOW! TURN SYSTEM OFF," the meter shall not be used until the batteries are replaced.

## 14. Calibration

14.1 This calibration procedure shall be performed before each round of water-level measurements.

14.1.1 Place water in the calibration test tube to a convenient level on the scale marked on the side of the tube.

14.1.2 Charge the internal tank of the water-level meter to 100 psi by attaching an oil-free air supply to the fitting marked "TANK RECHARGE."

14.1.3 Move the "SENSOR" switch to the "ON" position.

14.1.4 Wait for the LCD message to read "ATTACH TO WELL."

14.1.5 Attach the meter air tubing from the water-level meter fitting marked "TO AIR PROBE" to the air fitting on the top of the calibration test tube.

14.1.6 Move the "AIR" switch forward to the "ON" position.

14.1.7 Press the "START" button once.

14.1.8 Press the "AIR PRECHARGE" button until the LCD display reads the highest number.

14.1.9 Move the "AIR" switch back to the "OFF" position.

14.1.10 Wait for the LCD message to read "PROBE SUBMERSION DEPTH" and for the depth reading to stabilize.

14.1.11 Compare the meter reading to the actual water level in the calibration test tube. If the meter does not read the actual water level observed in the calibration test tube, remove the "CALIBRATION" panel screw and the epoxy seal from the internal calibration screw.

14.1.12 Slowly adjust the internal calibration screw until the meter reading matches the actual water level observed in the calibration test tube.

14.1.13 Repeat steps 14.1.3 through 14.1.11 to check the calibration.

14.1.14 Apply a small amount of epoxy or a similar locking compound to the calibration screw to lock it into position.

14.1.15 Reinstall the meter "CALIBRATION" panel screw.

## 15. Procedure Bias

15.1 The accuracy of this system of water-level measurements is  $\pm 0.01$  ft between 40 °F and 120 °F, and  $\pm 0.02$  ft between -20 °F and 40 °F.

## 16. Quality Assurance

16.1 The following information shall be logged when taking water-level measurements:

16.1.1 Date and time of measurements.

16.1.2 Well identification and site.

16.1.3 Name of person performing the measurement.

16.1.4 Reference point if not top of casing.

16.1.5 Remarks if necessary, e.g., wells pumping nearby, recent heavy rains, ice in well.

16.1.6 Depth to water.

16.1.7 Depths to top of LNAPLs and DNAPLs and thicknesses of layers (Method B only).

16.1.8 Length of dedicated water-level probe (Method C only).

16.1.9 Depth of submersion of water-level probe (Method C only).

16.1.10 Date and time of calibration and any calibration adjustments made (Method C only).

## 17. Keywords

17.1 Calibration test tube, conductivity cell, dedicated water-level probe, electric sounder, electronic/pneumatic water-level meter, interface probe, monitoring well, and probe submersion depth.

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Section A-2  
LQ-3(T)

## ***Environmental Procedures Catalog***

### **Document Addition/Revision**

**Procedure Title:** Standard Practice for Purging of Monitoring Wells, [LQ-3(P)], Rev. 1, 4/92

**Requester:** Tim Bartlett, Field Supervisor

**Justification:** (1) To establish project specific well purging/monitoring procedures and (2) to establish project specific policy regarding disposal of monitor well purge water.

**Proposed Change:** (1) Specific purge volume calculation and parameter stability criteria are defined in Section 4.2 of the *MMTS Interim Remedial Action Surface Water and Ground Water Monitoring Program* (MAC-MSGRAP 1.3.5-2). Section 4.2.1 documents requirements for managing purge water.

#### **Authorization for Changes to Catalog Procedures**

☐ New Document

☐ Change to Existing Procedure

☐ Adopt Procedure

Procedure Number Assigned \_\_\_\_\_

Procedure Title \_\_\_\_\_

Approval for Inclusion in Environmental Procedures Catalog:

\_\_\_\_\_  
Environmental Procedures Advisory Committee Chair

\_\_\_\_\_  
Date

#### **Authorization for Project Specific Modification to Existing Catalog Procedures**

Project Specific Change for *MMTS Operable Unit III, Interim Remedial Action Surface Water and Ground Water Monitoring Program* (MAC-MSGRAP 1.3.5-2)

Effective Date April 5, 1999

Reviewed By *Sam Capbell* 4-6-99  
Technical Author or Proficient Designee Date

Approved By *Walter McCall* 4/6/99  
Manager or Designee Date

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# Standard Practice for Purging of Monitoring Wells

## Introduction

To obtain a representative groundwater sample, the stagnant water in the well casing shall be removed. The recommended amount of purging depends on many factors such as the hydrogeological nature of the aquifer, the characteristics of the well, the type of sampling equipment to be used, and the parameters to be sampled. There is no one standard that will fit all situations. The general rule-of-thumb is to monitor the purge water using an in-line flow cell for pH, conductivity, and temperature. When these parameters stabilize to  $\pm 10$  percent for two successive well volumes, the sampler can be reasonably assured that the stagnant water has been removed from the well casing.

## 1. Scope

1.1 The four methods provided here are representative of those generally used to purge monitoring wells. Each method has advantages and disadvantages that must be considered. A review of Section 7, "Well Purging Strategies," General Considerations for the Sampling of Liquids [LQ-1(G)] (reference 3.2), provides guidance for selecting the proper method.

|                                                     | Section |
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| Method A—Well Purging Using a Peristaltic-Type Pump | 6-8     |
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| Method C—Well Purging Using a Bailer                | 12-14   |
| Method D—Well Purging Using a Submersible Pump      | 15-17   |

## 2. Hazard Analysis

2.1 These procedures use gasoline-powered electric generators, gasoline-powered air compressors, and battery-powered pumps and accessories. The following safety precautions shall be followed.

2.1.1 Air compressors that are belt driven shall have a belt guard in place.

2.1.2 Care shall be taken when connecting and disconnecting equipment powered by lead-acid batteries to avoid generating sparks that have the potential of creating an explosive hazard.

2.1.3 Gasoline shall be stored in Factory Mutual (FM)-approved safety cans. Safety cans shall be well secured in the vehicle during transport. Gasoline-powered equipment shall be cool before filling and care shall be taken not to spill any gasoline.

2.1.4 Air compressors shall not be operated above rated capacities and shall be configured to avoid having any dead end fittings above 20 pounds per square inch (psi). Carefully check for loose connections before operating.

2.1.5 Gasoline is a Department of Transportation (DOT)-regulated material; its hazard class is Flammable Liquid. Avoid eye and skin contact by wearing eye protection and disposable gloves. Avoid breathing vapors. Use only in a well-ventilated area and keep away from heat, sparks, and flames.

2.1.6 Gasoline-powered generators shall not be operated above their rated capacity.

2.1.7 Care shall be used when lifting generators and air compressors. Proper lifting techniques shall be used when lifting heavy equipment.

2.1.8 Site-specific controls are available in the planning documents for a particular project.

## 3. Referenced Documents

3.1 American Society for Testing and Materials, *Standard Guide for Sampling Groundwater Monitoring Wells*, D4448-85a, 1986.

3.2 Geotech, *Environmental Procedures Catalog* (Manual 116):

General Considerations for the Sampling of Liquids [LQ-1(G)],

Standard Test Method for the Measurement of Water Levels in Groundwater Monitoring Wells (LQ-2(T)).

Standard Practice for the Use of a Flow Cell for Field Measurements [LQ-10(P)].

3.3 U.S. Department of Energy, *The Environmental Survey Manual*, Appendix E, Volume 4, DOE/EH-0053 1987.



3.4 U.S. Environmental Protection Agency, *Practical Guide for Groundwater Sampling*, EPA/600/2-85/104, 1985.

3.5 U.S. Environmental Protection Agency, *Handbook Groundwater*, EPA/625/6-87/016, 1987.

#### 4. Significance and Use

4.1 Water may become stagnant in a well and will not reflect the local resident water's chemical and physical properties. The purging of a well can reduce this bias. Care shall be taken to allow screened intervals to come to equilibrium before sampling is performed

#### 5. Calculation of Volume of Standing Water in a Well

5.1 Calculations are performed for the amount of water in the well with the following formula:

$$r^2 \times \pi \times (h1 - h2) \times 7.48 = \text{gallons per casing volume,} \quad (1)$$

where

r = radius of well casing (feet) (the radius of the well is obtained from the well completion logs or can be measured with a tape measure),

h1 = depth of well (feet) from the top of the well casing (the depth of the well is obtained from the well completion logs), and

h2 = depth to water (feet) measured from the top of the well casing (the depth of water is measured using the Standard Test Method for the Measurement of Water Levels in Groundwater Monitoring Wells [LQ-2(T)]).

#### Method A

##### Well Purging Using a Peristaltic-Type Pump

#### 6. Apparatus

6.1 Peristaltic-type pump.

6.2 Silicone, C-FLEX, or neoprene tubing for the pump head.

6.3 Silicone, Teflon, polyethylene, or vinyl tubing for placing in the well.

6.4 Generator or other source of electricity.

6.5 Gasoline for generator. (Gasoline is a DOT-regulated material; its hazard class is Flammable Liquid.)

#### 7. Procedure

7.1 The following procedure is supplemental to the instruction in the instrument-specific operating manual.

7.1.1 Place the suction line in the well so it is just below the liquid surface.

7.1.2 Connect the suction line to the pump.

7.1.3 Connect the pump outlet to the in-line flow cell, see reference 3.2, or place the pump outlet hose into an open container to be used to make the field measurements.

7.1.4 Place calibrated pH, conductivity, and temperature electrodes into the in-line flow cell or the open container.

7.1.5 Initiate pumping and follow the water level down the well bore if the recovery rate of the well is below the pumping rate.

NOTE: Purge water may have to be contained and properly disposed of. Consult the site-specific planning documents for requirements.

7.1.6 Routinely monitor and record the volumes purged and the readings for the pH, conductivity, and temperature.

7.1.7 When these readings have stabilized to  $\pm 10$  percent for two successive well volumes, sampling can begin.

7.1.8 Remove the suction line from the well, and clean and decontaminate the suction line and pump tubing, as required.

#### 8. Procedure Bias

8.1 The advantages of purging with a peristaltic pump are that (1) a peristaltic pump is relatively portable, inexpensive, and convenient; (2) it requires a minimum of down-hole equipment; and (3) it can be cleaned easily or the entire tubing can be changed between wells.

8.2 The disadvantages of purging with a peristaltic pump are that (1) purging is limited to situations where the water levels are less than about 25 feet and (2) degassing occurs whenever there is a head difference between the pump and the water level.

### Method B Well Purging Using a Bladder-Type Pump

#### 9. Apparatus

- 9.1 Bladder-type pump.
- 9.2 Air compressor.
- 9.3 Teflon, polyethylene, or vinyl tubing for the air and sample line.
- 9.4 Gasoline for the air compressor. (Gasoline is a DOT-regulated material; its hazard class is Flammable Liquid.)

#### 10. Procedure

The following procedure is supplemental to the instruction found in the instrument-specific operating manual.

- 10.1 Lower the pump gently to a position just above the screened interval.
- 10.2 Connect the air line to the pump controller.
- 10.3 Connect the pump outlet to an in-line flow cell; see Standard Practice for the Use of a Flow Cell for Field Measurements [LQ-10(P)].
- 10.4 Place calibrated pH, conductivity, and temperature electrodes in the flow cell or the open container.
- 10.5 Initiate pumping and routinely monitor and record the volume purged and the pH, conductivity, and temperature measurements.

**NOTE:** Purge water may have to be contained and properly disposed of. Consult the site-specific planning documents for requirements.

- 10.6 When these readings have stabilized to  $\pm 10$  percent for two successive well volumes, sampling can begin.
- 10.7 Remove the pump from the well, clean and decontaminate as required.

#### 11. Procedure Bias

11.1 The advantages of using a bladder-type pump for purging are that (1) the system is not damaged by dry pumping, (2) there is no air/water contact, and (3) the entire assembly can be made of Teflon or stainless steel.

11.2 The disadvantages of using a bladder-type pump are that (1) pumping rates are relatively slow, (2) there is a high rate of air consumption during prolonged pumping, and (3) cleaning and decontamination are more difficult than with the apparatus used in methods A or C.

### Method C Well Purging Using a Bailer

#### 12. Apparatus

- 12.1 Teflon or stainless steel bailer.
- 12.2 Teflon or stainless steel cable or line.
- 12.3 Bailer reel.

#### 13. Procedure

- 13.1 Attach the bailer to the cable or line.
- 13.2 Lower the bailer slowly until it contacts the liquid.
- 13.3 Allow the bailer to sink until it is totally submerged.
- 13.4 Slowly raise the bailer to the surface.
- 13.5 Tip the bailer or use a bottom-emptying device and fill a container in which calibrated pH, conductivity, and temperature probes have been placed.

**NOTE:** Purge water may have to be contained and properly disposed of. Consult the site-specific planning documents for requirements.

- 13.6 Routinely monitor and record the pH, conductivity, temperature, and volume purged.
- 13.7 When the readings have stabilized to  $\pm 10$  percent for two successive well volumes, sampling can begin.
- 13.8 Clean and decontaminate the bailer, as required.

#### 14. Procedure Bias

14.1 The advantages of using bailers for well purging are that (1) bailers can be constructed of a variety of materials, (2) external power sources are not needed, (3) bailers are inexpensive, (4) bailers are easily cleaned and decontaminated, and (5) bailers can be used in wells of virtually any depth.

14.2 The disadvantages of using bailers are that (1) evacuating large amounts of stagnant water is labor intensive; (2) aeration, degasing, and turbulence will occur; (3) it is difficult to determine the depth to which the bailer has been submerged; and (4) bailer check valves may not operate properly under conditions of high suspended solids.

#### Method D Well Purging Using a Submersible Pump

### 15. Apparatus

15.1 Submersible-type pump.

15.2 Discharge tubing of vinyl, polyethylene, polyvinyl chloride, or Teflon.

15.3 Power source of generator or batteries.

15.4 Gasoline for generator. (Gasoline is a DOT-regulated material; its hazard class is Flammable Liquid.)

### 16. Procedure

The following procedure is supplemental to the instructions provided in the instrument-specific operating manual.

16.1 Set up the pump according to the operating manual.

16.2 Gently lower the pump down the well so that the pump head is submerged sufficiently and will not run dry.

**CAUTION:** Submersible pumps cannot be allowed to run dry.

16.3 Connect the pump outlet to an in-line flow cell; see Standard Practice for the Use of a Flow Cell for Field Measurements ([LQ-10(P)]).

16.4 Place calibrated pH, conductivity, and temperature electrodes in the flow cell or the open container.

16.5 Initiate pumping, and monitor and record the volumes purged and the pH, conductivity, and temperature measurements.

**NOTE:** Purge water may have to be contained and properly disposed of. Consult the site-specific planning documents for requirements.

16.6 When pH, conductivity, and temperature have stabilized for two successive well volumes, sampling can begin.

16.7 Remove the pump from the well; clean and decontaminate.

### 17. Procedure Bias

17.1 The advantages of using a submersible pump for well purging are that (1) relatively high pumping rates are possible, (2) some designs are relatively portable and easy to use, and (3) these pumps can pump from greater depths than the pumps used in methods A or B.

17.2 The disadvantages of using a submersible pump are that (1) high pumping rates and the mechanical actions cause turbulence, aeration, and degasing of the water; (2) pumps are easily damaged by dry pumping; and (3) these pumps can be difficult to clean and decontaminate.

### 18. Quality Assurance

18.1 All of the methods listed above require the following information to be logged for quality-assurance documentation.

18.1 Depth to water.

18.2 Depth of well.

18.3 Well diameter or radius.

18.4 Depth of water.

18.5 Calculated water volume.

18.6 Type of mechanism used to evacuate the well.

18.7 Date.

18.8 Well identification.

18.9 Name of person performing the purging.

18.10 Volume purged.

18.11 Conductivity, pH, and temperature measurements.

### 19. Keywords

19.1 Bailer, bladder-type pump, peristaltic-type pump, submersible pump, and well purging.



# Standard Test Method for the Field Measurement of pH

## Introduction

Perhaps no water-quality parameter is measured as frequently as pH. The pH measurement is so easily made that the attention given to it is often inadequate. An accurate pH is critical for the prediction and interpretation of the reactions and migration of dissolved species. This procedure provides a useful pH measurement under most field situations.

### 1. Scope

1.1 This is the procedure for the measurement of pH in an aqueous solution. The pH is determined using a glass hydrogen-ion electrode compared against a reference electrode of known potential by means of a pH meter.

### 2. Hazard Analysis

2.1 No hazards requiring controls have been identified. Site-specific controls are available in the planning documents of a particular project.

### 3. Referenced Documents

3.1 American Society for Testing and Materials, *Annual Book of ASTM Standards*, Section 11, Volume 11.01, D1293-78, 1984.

3.2 American Public Health Association, American Water Works Association, and Water Pollution Control Federation, *Standard Methods for the Examination of Water and Wastewater: American Public Health Association*, Washington, D.C., 1980.

3.3 Geotech, *Environmental Procedures Catalog*, Manual 116:

Standard practice for the Use of the Flow Cell for Field Measurements [LQ-10(P)].

3.4 Korte, N., and D. Ealey, *Procedures for Field Chemical Analyses of Water Samples*, Technical Measurements Center, U.S. Department of Energy, Grand Junction Area Office, GJ/TMC-07(83), 1983.

3.5 Wood, W.W., "Guidelines for Collection and Field Analysis of Ground-Water Samples for Selected Unstable Constituents," *Techniques of Water-Resources Investigations of the United States Geological Survey*, Chapter D2, Book 1: U.S. Government Printing Office, Washington, D.C., Stock Number 024-001-02879-4, 1976.

### 4. Significance and Use

4.1 The pH of a solution is defined as the negative logarithm to the base 10 of the hydrogen-ion activity in moles per liter:  $\text{pH} = -\log [H^+]$ . Because pH is exponentially related to concentration, great care shall be taken in making the measurement.

4.2 Natural waters usually have pH values in the range of 4 to 9. The primary control over pH in natural waters is the carbonate system, including gaseous and dissolved carbon dioxide, bicarbonate, and carbonate ions.

### 5. Interferences

5.1 Temperature, atmospheric contamination, and ionic strength are factors that affect pH measurements. The pH measurement is relatively free from interference from color, turbidity, colloidal matter, oxidants, or reductants.

5.1.1 *Temperature*—The temperature compensation on a pH meter only permits adjustment of the electrode slope. It does not compensate for changes in the potential of the reference electrode, the asymmetry potential of the glass electrode, or the liquid-junction potential. Nor does it compensate for changes in pH due to temperature. Thus, the temperature of the buffer and the unknown shall be recorded at the time of measurement. Ideally, their temperatures shall be within 10 °C.

5.1.2 *Atmospheric Contamination*—Atmospheric contamination can be a significant problem for groundwater samples. Dissolved oxygen and carbon dioxide can be evolved or dissolved when the sample is exposed to air, and a considerable change in pH may result. In situ measurements should be taken where possible but, for groundwater that must be pumped, the use of a flow cell gives the best results. See Standard Practice for the Use of a Flow Cell for Field Measurements [LQ-10(P)].

5.1.3 *Ionic Strength*—Because of errors due to ionic strength (which are not worth correcting in



the field), pH measurements shall be accompanied by a measurement of the specific conductance. The pH is a measurement of the hydrogen-ion activity. An ideal solution is assumed in which other ions do not affect the hydrogen activity. This assumption deteriorates if the ionic strength is too high. Similarly, samples with low ionic strength will cause difficulties because the resistance of the sample approaches that of the glass electrode. For best results, samples with very low ionic strength should be stirred for a few seconds prior to the reading. Even then, it may require several minutes for the reading to stabilize.

5.1.4 *High Sodium and Alkalinity*—High sodium and alkalinity may also produce errors in the pH measurement. For pH 9 and a sodium concentration of 10 moles per liter, a special electrode is needed. Similarly, any pH value that is less than 1 or greater than 9 will have a greater uncertainty associated with it because the electrode response is non-Nernstian in these regions.

## 6. Apparatus

6.1 Numerous pH meters are available; the meter used should have a temperature compensating device have a slope adjustment and be capable of reading pH to  $\pm 0.01$  units.

6.2 A flow cell to be used for continuous-flow measurements.

6.3 Standard pH-buffer solutions of 4.00, 7.00, and 9.00 or 10.00.

6.4 Combination pH electrode.

6.5 Temperature-measuring device capable of reading temperatures to  $\pm 0.1$  °C.

6.6 Distilled or deionized water in a squeeze wash bottle.

6.7 Kimwipes or equivalent lint-free tissue.

6.8 Disposable beakers, test tubes, or centrifuge tubes.

## 7. Calibration

7.1 In each case, samplers shall follow the manufacturer's instructions for the pH meter and electrode used. Electrodes shall be kept wet when not in use. Recommended solutions for storage are the pH 4.00 or pH 7.00 buffer.

7.2 Before use, remove the electrode from the storage solution, rinse with distilled water, and blot dry with a lint-free tissue.

7.3 Adjust buffer solution and electrode to  $\pm 10$  °C of the sample temperature. This can be done by storing the buffer solutions and electrode in an ice chest or by letting sample water run over the buffer bottles and electrode until the temperatures have equilibrated.

7.4 Place the electrode in the pH 7.00 buffer, adjust the temperature compensation control to the temperature of the buffer (or use an automatic temperature compensator), and adjust the calibration control to read the pH of the buffer. The pH of the buffer is equal to 7.00 only at 25 °C; therefore, it is necessary to use the temperature-correction curve supplied by the manufacturer of the buffer.

7.5 Remove the electrode from the 7.00 buffer, rinse with distilled water, and blot dry. Place the electrode in either pH 4.00 or pH 10.00 buffer, bracketing the expected pH of the sample. Allow the reading to stabilize before making adjustments. Adjust the slope control to read the correct pH, again consulting the temperature-correction curve supplied by the manufacturer.

7.6 Rinse the electrode with distilled water and blot dry. Recheck value of the pH 7.00 buffer. The value shall be within  $\pm 0.02$  pH of the correct value. If not, repeat steps 7.4, 7.5, and 7.6.

## 8. Procedure

8.1 The following general procedure supplements the instruction in the instrument-specific operating manual.

8.1.1 Rinse the calibrated electrode (see Section 7) with distilled water, blot dry, and immerse electrode in the solution.

8.1.2 Use of a flow cell is recommended for making pH measurements; this reduces the interferences due to atmospheric contamination. If possible, in situ measurements are the best.

8.1.3 Allow the measurement to stabilize and record the reading.

8.1.4 Remove the electrode from the solution, rinse with distilled water, blot dry, and store in pH 4.00 or pH 7.00 buffer solution.

## 9. Quality Assurance

9.1 The following information about the field measurement of pH shall be logged for quality-assurance documentation.

9.1.1 Time of the last two-buffer calibration. The two-buffer calibration shall be performed a minimum of once each hour.

9.1.2 Buffer temperature at time of calibration.

9.1.3 Sample temperature at time of measurement.

9.1.4 Measurement conditions (i.e., in situ, open container, or air-exclusion container).

9.1.5 Source and expiration date of buffers used.

9.1.6 Instrument manufacturer and model number.

9.1.7 Name of person performing the measurement.

## 10. Precision and Bias

10.1 Precision of  $\pm 0.02$  pH units and an accuracy of  $\pm 0.05$  pH units can be achieved. However,  $\pm 0.1$  pH units represent the limit of accuracy under normal conditions.

## 11. Keywords

11.1 Electrode, flow cell, pH, and pH meter.



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## ***Environmental Procedures Catalog***

### **Document Addition/Revision**

**Procedure Title:** Standard Test Method for the Field Measurement of Specific Conductance, [LQ-5(T)], Rev. 1, 4/92

**Requester:** Tim Bartlett, Field Supervisor

**Justification:** A three point operational check is required to determine if the instrument is responding properly through a wide range of conductivities. However, this three-point check is not necessary at every sampling site due to the limited range of conductivities expected.

**Proposed Change:** Section 7 - A three-point conductivity check will be performed on each probe at the start and finish of each sampling day. Calibration prior to sampling will be documented in the field data book. Daily checks will be recorded in the field logbook. After the initial check a one-point check with a 1000 mhos/cm solution will be performed at each sampling location prior to sampling. The three-point check may be conducted using commercially available KCl solutions of 100 mhos/cm, 1000 mhos/cm, and 10,000 mhos/cm or using reagent grade KCl solutions of known normality.

#### **Authorization for Changes to Catalog Procedures**

☐ New Document                                      ☐ Change to Existing Procedure                                      ☐ Adopt Procedure

Procedure Number Assigned \_\_\_\_\_

Procedure Title \_\_\_\_\_

Approval for Inclusion in Environmental Procedures Catalog:

\_\_\_\_\_  
Environmental Procedures Advisory Committee Chair

\_\_\_\_\_  
Date

#### **Authorization for Project Specific Modification to Existing Catalog Procedures**

Project Specific Change for MMTS Operable Unit III, Interim Remedial Action Surface Water and Ground Water Monitoring Program (MAC-MSGRAP 1.3.5-2)

Effective Date April 5, 1999

Reviewed By Sam Campbell 4-6-99  
Technical Author or Proficient Designee                                      Date

Approved By Michael McMillan 4/6/99  
Manager or Designee                                      Date

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# Standard Test Method for the Field Measurement of Specific Conductance

## Introduction

Specific conductance is a widely used indicator of water quality. It measures the ability of water to carry an electrical current under specific conditions. This ability depends on the presence of ions and their total concentration, mobility, and temperature. Specific conductance is a simple indicator of change within a system and is used as an aid in evaluating whether a sample is representative of the water in the system.

### 1. Scope

1.1 This procedure describes the field measurement of the specific conductance of an aqueous sample. The specific conductance is measured using a conductance meter and a platinum or stainless steel electrode.

### 2. Hazard Analysis

2.1 No hazards requiring controls have been identified. Site-specific controls are available in the planning documents for a particular project.

### 3. Referenced Documents

3.1 American Public Health Association, American Water Works Association, and Water Pollution Control Federation, *Standard Methods for the Examination of Water and Wastewater: American Public Health Association*, Washington, D.C., 1980.

3.2 Korte, N. and D. Ealey, *Procedures for Field Chemical Analyses of Water Samples*, Technical Measurements Center, U.S. Department of Energy, Grand Junction Area Office, GJ/TMC-07(83), 1983.

3.3 Wood, W.W., "Guidelines for Collection and Field Analysis of Ground-Water Samples for Selected Unstable Constituents," *Techniques of Water-Resources Investigations of the United States Geological Survey*, Chapter D2, Book 1: U.S. Government Printing Office, Washington, D.C., Stock Number 024-001-02879-4, 1976.

### 4. Significance and Use

4.1 The specific conductance or conductivity of a sample is defined as the conductance of the sample between opposite sides of a cube, 1 centimeter (cm) in each direction. Because it is impractical to build electrodes with these characteristics,

electrodes are manufactured in various forms. A cell constant is determined by measuring a solution of known conductivity. Solutions of known conductivity are purchased or can be made from reagent-grade KCl. Samplers shall consult operating instructions for the specific instrument used for the determination of the cell constant. This conductivity is expressed in micromhos per centimeter ( $\mu\text{mhos/cm}$ ).

### 5. Interferences

5.1 Temperature, ionic strength, and the determination of the cell constant are features that affect the measurement of conductivity.

5.1.1 *Temperature*—The conductivity of a solution increases with temperature at approximately 2 percent per degree celsius. Significant errors can result from inaccurate temperature measurements.

5.1.1.1 If the conductivity meter does not have automatic temperature correction, the sampler can use the following formula to correct the conductivity reading for temperature:

$$K = \frac{E_m}{1 + 0.0191(t - 25)} \quad (1)$$

where

K = corrected conductivity in  $\mu\text{mhos/cm}$ ,

$E_m$  = measured conductivity in  $\mu\text{mhos/cm}$ ,  
and

t = temperature in  $^{\circ}\text{C}$ .

5.1.2 *Ionic Strength*—The conductivity of a solution is a function of the concentration and charge of the ions in solution and of the rate at which the ions move under the influence of an electrical potential. As the ionic strength increases, the rate at

which the individual ions move decreases. Conductivity varies linearly with ionic strength for values below 1,000  $\mu$  mhos/cm. As conductivity increases above 5,000  $\mu$  mhos/cm, the line curves significantly; beyond 50,000  $\mu$  mhos/cm, the conductivity is an unsatisfactory index of ionic concentration.

**5.1.3 Cell Constant**—The cell constant shall be checked and verified on a regular basis. A significant change in the cell constant indicates that the electrode needs cleaning or changing. Consult the instrument operating manual for procedures to check the cell constant, or see Section 7 of this procedure.

## 6. Apparatus

**6.1** Specific conductance meter capable of measuring conductivity in the range of 0 to 100,000  $\mu$  mhos/cm. This meter should also measure temperatures in the range of  $-5^{\circ}\text{C}$  to  $50^{\circ}\text{C}$ .

**6.2** Conductivity check solutions. Normally, 0.001 N, 0.01 N, and 0.1 N KCl solutions will cover the range of expected sample conductivity.

**6.3** Distilled or deionized water in a squeeze bottle.

**6.4** Disposable beakers, test tubes, or centrifuge tubes.

**6.5** Kimwipes or equivalent lint-free tissue.

## 7. Calibration

**7.1** An actual calibration of the instrument is not performed. The cell/instrument calibration is confirmed by use of standard check solutions as described below.

**7.1.1** Connect the temperature probe and conductivity cell to the instrument.

**7.1.2** Rinse the temperature probe and conductivity cell with distilled water and blot dry with a lint-free tissue.

**7.1.3** Place the temperature probe and conductivity cell in the 0.001 N KCl standard and allow the readings to stabilize. Record the temperature and conductivity reading in the field logbook.

**7.1.4** Repeat steps 7.1.2 and 7.1.3 for the 0.01 N and the 0.1 N KCl standards.

**7.1.5** Correct the readings to  $25^{\circ}\text{C}$  using the formula in Section 5.1.1.1 and compare these readings to the standard values. If these readings are within  $\pm 10$  percent of the accepted value, the cell instrument-calibration check is acceptable.

**7.1.6** If the cell/instrument calibration check is unacceptable, consult the instrument operation manual for cell cleaning and instrument troubleshooting procedures.

## 8. Procedure

**8.1** The following general procedure is supplemental to the instructions in the instrument-specific operating manual.

**8.1.1** Rinse the conductivity cell and temperature probe with several volumes of sample water.

**8.1.2** Immerse the probe and cell in the sample.

**8.1.3** Allow the readings to stabilize and record the temperature and conductivity readings on the field log form.

**8.1.4** Remove the probes from the solution, rinse with distilled water, blot dry, and store according to the manufacturer's recommended procedures.

## 9. Quality Assurance

**9.1** The following information about the field measurement of specific conductance shall be logged for quality-assurance documentation.

**9.1.1** Source and expiration date of standards.

**9.1.2** Instrument manufacturer and model number.

**9.1.3** Date and time of calibration check.

**9.1.4** Temperature and conductivity of standards used to check calibration.

**9.1.5** Sample temperature and conductivity reading.

**9.1.6** Name of person performing the measurement.

## 10. Precision and Bias

**10.1** Precision and accuracy of  $\pm 5$  percent can be achieved with this procedure at conductivity readings between 100 and 5,000  $\mu$  mhos/cm.

Readings between 0 and 100  $\mu$ mhos/cm and above 5,000  $\mu$ mhos/cm should provide  $\pm$  10 percent precision and accuracy. Readings above 20,000  $\mu$ mhos/cm shall not be attempted with this procedure.

## 11. Keywords

11.1 Conductivity, ionic strength, and specific conductance.





# Standard Test Method for the Field Measurement of the Oxidation-Reduction Potential (ORP) for Calculation of Eh

## Introduction

Knowledge of the Eh of a system is useful for predicting the migration or attenuation of contaminants in groundwater or surface water. However, the oxidation-reduction potential (ORP) measurement should be used with caution. Only under certain conditions are ORP measurements from which the Eh is calculated reliable. Therefore, the resulting Eh value is primarily used as a descriptive tool.

### 1. Scope

1.1 This method describes the procedure for the measurement of ORP in aqueous samples and calculation of Eh. It does not address the theoretical interpretation of ORP. This procedure has been designed for routine field measurements.

### 2. Hazard Analysis

2.1 This test method uses a ZoBell solution for an Eh reference. This solution contains small concentrations of potassium cyanide. Potassium cyanide is a poison and should be handled with care. Samplers shall wear eye protection and disposable gloves to avoid eye and skin contact and shall keep the solution away from strong acids that will liberate hydrogen cyanide gas, which is extremely toxic.

2.2 Site-specific controls are available in the planning documents for a particular project.

### 3. Referenced Documents

3.1 American Society for Testing and Materials, *Annual Book of ASTM Standards*, Section 11, Volume 11.01, D1498-76, 1984

3.2 Korte, N., and D. Ealey, *Procedures for Field Chemical Analyses of Water Samples*, Technical Measurements Center, U.S. Department of Energy, Grand Junction Area Office, GJ/TMC-07(83), 1983

3.3 "Guidelines for Collection and Field Analysis of Ground-Water Samples for Selected Unstable

Constituents", in *Techniques of Water-Resources Investigations of the United States Geological Survey*, Chapter D2, Book 1: U.S. Government Printing Office, Washington, D.C., Stock Number 024-001-02879-4, 1976

### 4. Significance and Use

4.1 ORP is defined as the electromotive force developed when a noble metal electrode and a reference electrode are placed in an aqueous sample. This potential, sometimes referred to as the redox potential, is related to the standard potential by the Nernst equation:

$$E_h = E^\circ + \frac{RT}{nF} \ln \frac{\text{oxidized state}}{\text{reduced state}}$$

where

E = standard potential of the reaction,

R = gas constant,

T = absolute temperature,

n = number of electrons involved in the half-cell reaction, and

F = Faraday constant.

The potential is reported as volts (V) or millivolts (mV) relative to the standard hydrogen electrode taken as zero.

## 5. Interferences

5.1 ORP measurements are sensitive to temperature change of the solution. Because the reference-electrode potential and the liquid-junction potential also vary with temperature, instrumental compensation is not possible. Reference solutions used to check the accuracy of the electrode system should be within  $\pm 10^\circ\text{C}$  of the sample temperature for the readings to be valid.

5.2 Reproducible ORP measurements cannot be obtained for chemical systems that are not reversible. Samples containing dissolved oxygen above 0.01 part per million (ppm) are essentially irreversible, and ORP measurements of these samples are not recommended. Because exposure to the atmosphere can cause rapid changes in dissolved oxygen, all sample measurements shall be taken in a closed, flow-through container or in situ.

5.3 Samples containing hydrogen sulfide will poison the electrode as will other ions that are stronger reducing agents than platinum.

5.4 ORP measurements are relatively free from interferences from color, turbidity, colloidal matter, and suspended matter.

## 6. Apparatus

6.1 Most field pH meters have the capability of measuring ORP by substitution of an appropriate set of electrodes. The meter should be capable of measuring ORP to  $\pm 1$  mV.

6.2 Combination ORP/En electrode.

6.3 ZoBell reference solution.

**Caution:** This solution is poisonous and shall be handled with care.

6.4 Temperature-measuring device capable of reading temperatures to  $\pm 0.1^\circ\text{C}$ .

6.5 A flow cell. See Standard Practice for the Use of a Flow Cell for Field Measurements [LQ-10(P)].

6.6 Distilled or deionized water in a squeeze wash bottle.

6.7 Kimwipes or equivalent lint-free tissue.

6.8 Disposable beakers, test tubes, or centrifuge tubes.

## 7. Calibration

7.1 An actual calibration of the ORP electrode system is not performed. Instead, samplers shall make a performance check to determine if the electrode and meter are functioning properly. The performance check is as follows:

7.1.1 Record temperature of ZoBell solution. This solution should be within  $\pm 10^\circ\text{C}$  of sample temperature.

7.1.2 Place electrode in the ZoBell solution and compare the reading with the theoretical value for the ZoBell solution (see Figure 1). The reading should be within  $\pm 10$  mV of the theoretical value.

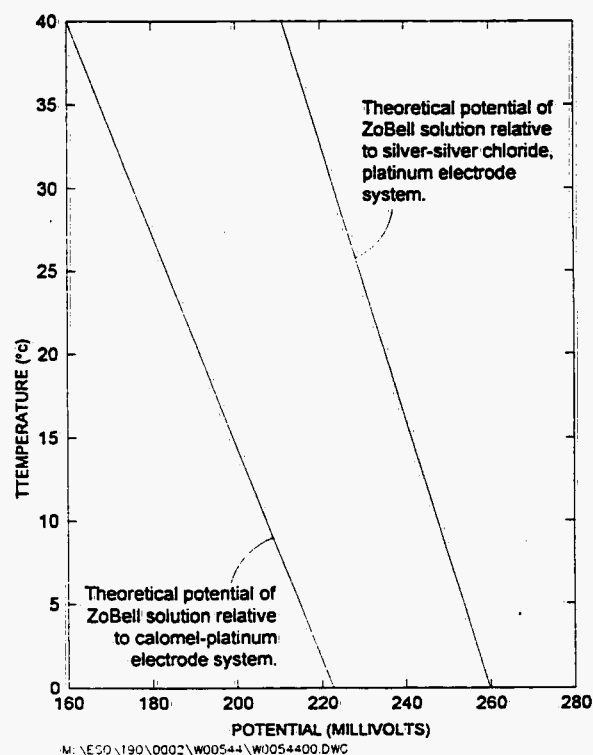


Figure 1. The potential of ZoBell Solution Relative to Reference-Electrode Systems at Various Temperatures

7.1.3 If the reading is not within  $\pm 10$  mV, one of the following steps will usually solve the problem.

7.1.3.1 Check reference-electrode filling solution; fill or replace.

7.1.3.2 Polish the platinum end of the electrode (see manufacturer's instructions).

7.1.3.3 Replace electrode.

7.1.4 Rinse electrode with distilled water, blot dry, and store according to manufacturer's suggestions.

## 8. Procedure

8.1 Check electrode performance according to section 7.1.2.

8.2 Rinse electrode with distilled water and blot dry with a lint-free tissue.

8.3 Place electrode in flow-through cell and pump sample through cell for several minutes to exclude air.

8.4 Turn function switch on meter to the millivolt mode.

8.5 Allow the readings to stabilize. Stabilization should occur within 20 minutes. Turn off sample flow to prevent any streaming potential.

8.6 Record the **ORP** reading and temperature.

8.7 Remove the electrode from the cell, rinse with distilled water, blot dry, and store according to manufacturer's suggestion.

## 9. Quality Assurance

9.1 The following information about the **ORP** measurement shall be logged for quality-assurance documentation.

9.1.1 Temperature of sample.

9.1.2 Temperature of ZoBell solution.

9.1.3 **ORP** of ZoBell solution.

9.1.4 Name of person performing the measurement.

## 10. Calculation

10.1 The Eh of the sample is calculated relative to the standard hydrogen electrode as follows:

$$D = A - B + C,$$

where

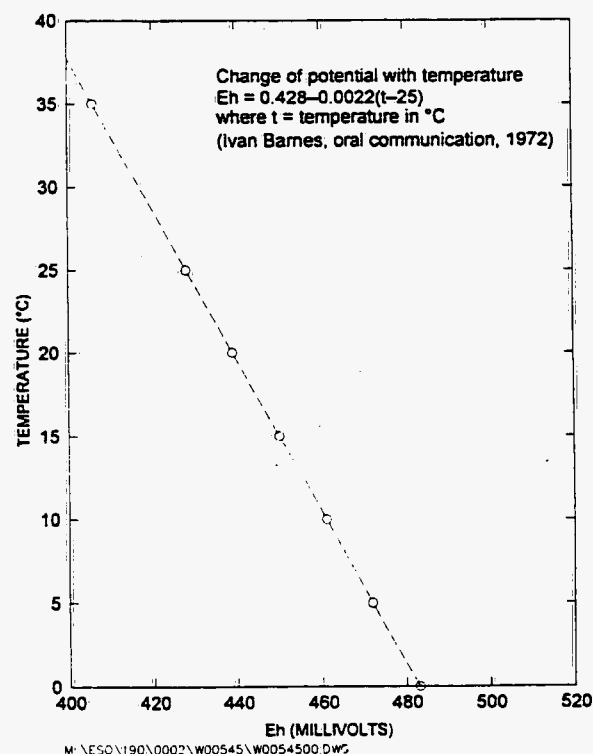
D = Eh of sample relative to the standard hydrogen electrode,

A = Observed **ORP** of sample,

B = Observed **ORP** of ZoBell solution, and

C = Theoretical Eh of ZoBell solution relative to the standard hydrogen electrode **Figure 2**

Report D to the nearest  $\pm 10$  mV.



**Figure 2. The Eh of Zobell Solution, Relative to the Standard Hydrogen Electrode at Various Temperatures**

## 11. Precision and Bias

11.1 Precision and accuracy of the measurement depend largely on the condition of the electrode system and the degree to which the sample fits the interference problems mentioned in section 5. In the absence of substances that coat or poison the electrode, the precision is  $\pm 10$  mV.

## 12. Keywords

12.1 Eh, flow cell, oxidation-reduction potential, and ZoBell solution



# Standard Test Method for the Field Measurement of Alkalinity

## Introduction

The alkalinity of a water sample is a quantitative measurement of the ability of the sample to react with a strong acid to a designated pH. The alkalinity of natural waters is primarily a measure of the carbonate, bicarbonate, and hydroxide content. It is also a general indicator of groundwater quality.

### 1. Scope

1.1 This method describes the field measurement of alkalinity of aqueous samples. It is a measure of the aggregate property of the sample and can be interpreted in the terms of specific substances, such as carbonate and bicarbonate, only when the chemical composition of the sample is known.

1.2 The sample is titrated with a standard acid solution to a designated pH, and the end point is determined by a color change of an internal indicator.

### 2. Hazard Analysis

2.1 This test procedure uses sulfuric acid ( $\text{H}_2\text{SO}_4$ ). Sulfuric acid is a corrosive material and is a Department of Transportation (DOT)-regulated material; its hazard class is Corrosive Liquid. Avoid contact with eyes, skin, and clothing. Adequate ventilation, eye protection, and disposable gloves are required. First aid for eye and skin contact is to immediately flush with water for 15 minutes, remove contaminated clothing, and call a physician.

2.2 Site-specific controls are available in the planning documents for a particular project.

### 3. Referenced Documents

3.1 American Public Health Association, *Standard Methods for the Examination of Water and Wastewater*, American Water Works Association, and Water Pollution Control Federation, Washington, D.C., 1980.

3.2 American Society for Testing and Materials, *Annual Book of ASTM Standards*, Section 11, Volume 11.01, 1984.

3.3 Geotech, *Environmental Procedures Catalog* (Manual 116):

Standard Test Method for the Field Measurement of pH [LQ-4(T)].

3.4 Korte, N., and D. Ealey, *Procedures for Field Chemical Analyses of Water Samples*, Technical Measurements Center, U.S. Department of Energy, Grand Junction Area Office, GJ/TMC-07(83), 1983.

3.5 Wood, W. W., "Guidelines for Collection and Field Analysis of Ground-Water Samples for Selected Unstable Constituents," *Techniques of Water-Resources Investigations of the United States Geological Survey*, Chapter D2, Book 1: U.S. Government Printing Office, Washington, D.C., Stock Number 024-001-02879-4, 1976.

### 4. Significance and Use

4.1 The alkalinity of natural water is commonly used to obtain a value for the carbonate and bicarbonate concentrations. Carbonate and bicarbonate determinations shall be made in the field at the time of sampling if the concentrations are to accurately reflect those concentrations originally present in the sample.

4.2 The following equations govern the reactions involved:

$\text{CO}_3^{2-} + \text{H}^+ = \text{HCO}_3^-$  (this reaction is complete near pH 8.3),

$\text{HCO}_3^- + \text{H}^+ = \text{H}_2\text{O} + \text{CO}_2$  (this reaction is complete near pH 4.5).

The end point of pH 8.3 is determined by the color change of the phenolphthalein indicator, and the end point of pH 4.5 is determined by the color change of the bromocresol green-methyl red indicator.

**NOTE:** If the measured pH of the sample is less than 4.5, there is no carbonate or bicarbonate alkalinity and this test method is not applicable.

## 5. Interferences

5.1 The measured values may include contributions from borates, phosphates, or silicates if these are present in the sample.

5.2 Natural color or the formation of precipitate while titrating the sample may mask the color change of the indicator, or waste materials may interfere chemically with the color change by destroying the indicator.

5.3 Varying results may be experienced with samples containing oxidizing or reducing substances.

## 6. Apparatus

6.1 Hach alkalinity test kit Model AL-DT. (This kit contains sulfuric acid, which is a DOT-regulated material; its hazard class is Corrosive Liquid.)

6.2 Distilled or deionized water in a squeeze bottle.

6.3 Kimwipes or equivalent lint-free tissue.

## 7. Procedure

7.1 Attach a clean, straight-stem delivery tube to a sulfuric acid titration cartridge. If the expected alkalinity is below 100 milligrams per liter (mg/L) as  $\text{CaCO}_3$ , use a 0.16 N  $\text{H}_2\text{SO}_4$  cartridge; if it is above 100 mg/L as  $\text{CaCO}_3$ , use a 1.6 N  $\text{H}_2\text{SO}_4$  cartridge; or if it is above 1,000 mg/L, use an 8.0 N  $\text{H}_2\text{SO}_4$  cartridge. Twist the cartridge onto the titrator body.

7.2 Flush out the delivery tube by turning the small knob until a few drops of titrant are ejected from the tube. Wipe the tip and reset the counter to zero. Ensure that there are no air bubbles in the cartridge.

7.3 Take a sample by filling a clean 100-mL graduated cylinder to the 100-mL mark with water that has been filtered through a 0.45 micrometer ( $\mu\text{m}$ ) filter. Pour the sample into a clean 250-mL Erlenmeyer flask.

7.4 Measure the pH of the sample; see Standard Test Method for the Field Measurement of pH [LQ-4(T)]. If the pH of the sample is less than 8.3, proceed to step 7.8; if the pH of the sample is greater than 8.3, proceed to step 7.5.

7.5 Add the contents of one phenolphthalein indicator Powder Pillow and swirl to mix.

7.6 If the color turns pink, titrate with the sulfuric acid standard solution to a colorless end point. If the pink color does not develop, proceed with step 7.8.

7.7 Read and record the amount of acid used. This is the amount of carbonate alkalinity, sometimes referred to as phenolphthalein alkalinity. See section 8 for calculations.

7.8 Add the contents of one bromocresol green-methyl red indicator Powder Pillow to the sample and swirl to mix.

7.9 Titrate the sample with the sulfuric acid standard solution until a light pink color is obtained. Read and record the amount of acid used. This is the amount of total alkalinity. See section 8 for calculations.

7.10 Pour the titrated sample into a properly labeled disposal container, rinse the Erlenmeyer flask and the graduated cylinder with distilled or deionized water, and place the items back in the kit.

## 8. Calculations

8.1 The results are reported in mg/L as  $\text{CaCO}_3$ . The calculation depends on the normality of the sulfuric acid titration cartridge used. The calculations are performed as follows.

8.1.1 When using the 0.16 N  $\text{H}_2\text{SO}_4$  titration cartridge, the digital readout from the titrator is multiplied by 0.1 to obtain alkalinity results in mg/L as  $\text{CaCO}_3$ .

8.1.2 When using the 1.6 N  $\text{H}_2\text{SO}_4$  titration cartridge, the results from the digital readout of the titrator are equivalent to mg/L as  $\text{CaCO}_3$ .

8.1.3 When using the 8.0 N  $\text{H}_2\text{SO}_4$  titration cartridge, the results from the digital readout of the titrator are multiplied by 5.0 to obtain alkalinity in mg/L as  $\text{CaCO}_3$ .

## 9. Quality Assurance

9.1 The following information about the field measurement of alkalinity shall be logged for quality-assurance documentation.

9.1.1 Normality of the titration cartridge.

9.1.2 Phenolphthalein alkalinity.

9.1.3 Total alkalinity.

9.1.4 Name of person performing the measurement.

#### **10. Precision and Bias**

10.1 Under normal conditions, precision and accuracy of  $\pm 15$  percent can be expected from this procedure.

#### **11. Keywords**

11.1 Alkalinity, bicarbonate, carbonate, and titration.



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# Standard Test Method for the Field Measurement of Temperature

## Introduction

Temperature readings are important for numerous applications. They are used in the measurement of Eh, pH, conductivity, and dissolved oxygen; and in saturation and stability studies. It is important to know the temperature of surface waters and groundwaters for the accurate geochemical evaluation of equilibrium thermodynamics. Temperature readings of  $\pm 1^\circ\text{C}$  are necessary for the above applications.

### 1. Scope

1.1 This procedure gives general guidance and recommendations that shall be considered when taking a temperature measurement. There are numerous instruments on the market that can provide adequate temperature measurements. Each instrument-operating manual shall be consulted for detailed procedures.

### 2. Hazard Analysis

2.1 No hazards requiring controls have been identified. Site-specific controls are available in the planning documents for a particular project.

### 3. Referenced Documents

3.1 American Public Health Association, *Standard Methods for the Examination of Water and Wastewater*, American Water Works Association, and Water Pollution Control Federation, Washington, D.C., 1980.

3.2 Wood, W.W., "Guidelines for Collection and Field Analysis of Ground-Water Samples for Selected Unstable Constituents," *Techniques of Water-Resources Investigations of the United States Geological Survey*, Chapter D2, Book 1: U.S. Government Printing Office, Washington, D. C., Stock Number 024-001-02879-4, 1976.

### 4. Significance and Use

4.1 Temperature is a basic physical property that is measured by the response of matter to heat. There are many devices that, once calibrated, are acceptable for taking temperature measurements. These devices include liquid in glass (mercury in glass), thermocouples, bimetallic, and electrical-resistance thermometers. At a minimum, the device should measure temperature to  $\pm 0.1^\circ\text{C}$  readability.

### 5. Interferences

5.1 The instrument-operating manual shall be consulted to identify any interferences particular to the device being used.

5.2 In general, the true sample temperature is affected by the atmospheric temperature of the surroundings and the temperature of the devices used to collect the sample.

### 6. Apparatus

6.1 Temperature-measuring device.

6.2 Distilled or deionized water in a squeeze wash bottle.

6.3 Kimwipes or equivalent lint-free tissue.

### 7. Calibration

7.1 The instrument-operating manual shall be consulted for specific calibrating procedures.

### 8. Procedure

8.1 Rinse the thermometer with distilled or deionized water and blot dry.

8.2 Immerse the thermometer in the sample.

8.3 Allow the reading to stabilize and record the temperature.

### 9. Quality Assurance

9.1 The following information about the temperature measurement shall be logged for quality-assurance documentation.

9.1.1 Instrument used.

9.1.2 Temperature of sample.

9.1.3 Name of person performing the measurement.

## 10. Precision and Bias

10.1 Precision is instrument-dependent. Most measurement devices for field use are accurate to  $\pm 0.1^{\circ}\text{C}$ .

## 11. Keywords

11.1 Temperature and thermometer.

Section A-8  
LQ-9(T)

# Standard Test Method for the Field Measurement of Dissolved Oxygen

## Introduction

Dissolved oxygen (DO) is required for the survival and growth of many aquatic organisms and the absence of dissolved oxygen may permit anaerobic decay of organic matter and the production of toxic and esthetically undesirable materials in the water. The measurement of dissolved oxygen is needed to accurately characterize the oxidation-reduction potential of a hydrologic system and can be an indicator of atmospheric contact of water before recharge to an aquifer.

### 1. Scope

1.1 This method contains the field procedures used to determine dissolved oxygen in aqueous samples using a polarographic technique with a membrane-covered electrode. The probe method is much more rapid and efficient than other methods, has fewer interferences, and can be used for continuous monitoring.

### 2. Hazard Analysis

2.1 This test method uses sodium sulfite and cobaltous chloride for the preparation of the zero-oxygen check solution. These chemicals are toxic in the concentrated form and the following precautions must be taken in the preparation of this solution. Avoid contact with the eyes and skin. Avoid breathing suspended particles. Adequate ventilation, eye protection, and disposable gloves are required. First aid for eye contact is to flush the eyes with water for 15 minutes and contact a physician. First aid for skin contact is to wash the area thoroughly with soap and water.

2.2 Site-specific controls are available in the planning documents for a particular project.

### 3. Referenced Documents

3.1 American Public Health Association, American Water Works Association, and Water Pollution Control Federation, *Standard Methods for the Examination of Water and Wastewater: American Public Health Association*, Washington, D.C., 1980.

3.2 American Society for Testing and Materials, *Annual Book of ASTM Standards*, Section 11, Volume 11.01, 1984.

3.3 Geotech, *Environmental Procedures Catalog*, Manual 116:

Standard Practice for the Use of a Flow Cell for Field Measurements [LQ-10(T)].

3.4 Korte, N., and D. Ealey, *Procedures for Field Chemical Analyses for Water Samples*, Technical Measurements Center, U.S. Department of Energy, Grand Junction Area Office, GJ/TMC-07(83), 1983.

3.5 Wood, W.W., "Guidelines for Collection and Field Analysis of Ground-Water Samples for Selected Unstable Constituents," *Techniques of Water-Resources Investigations for the United States Geological Survey*, Chapter D2, Book 1: U.S. Government Printing Office, Washington, D.C., Stock Number 024-001-02879-4, 1976.

### 4. Significance and Use

4.1 Oxygen-sensitive membrane electrodes are composed of two solid metal electrodes separated from the sample by an oxygen-permeable membrane. The membrane serves as a diffusion barrier against impurities. The rate of oxygen diffusion across the membrane creates a current that is directly proportional to the amount of dissolved oxygen in the sample. This current is converted to concentration units during the calibration.

### 5. Interferences

5.1 Membrane electrodes are sensitive to temperature variations. Most DO meters have automatic temperature compensators that correct for these variations. If not, thermal equilibrium must be established between the sample being measured and the calibrating solution.

5.2 Oxygen-permeable membranes are also permeable to other gases that can affect the measurement. Chlorine and hydrogen sulfide will eventually desensitize the probe during long-term exposures. These gases are not normally found in

groundwater samples, or their concentrations are too small to cause significant problems.

5.3 Because atmospheric oxygen is rapidly absorbed by water samples, use of an air-exclusion chamber is required if in situ measurements cannot be made.

## 6. Apparatus

6.1 Dissolved oxygen meter, Yellow Springs Instruments (YSI) Model 57.

6.2 Yellow Springs Instruments (YSI) 5739 dissolved-oxygen probe.

6.3 Bottle of electrolyte and extra membranes for probe.

6.4 Sodium sulfite and cobaltous chloride.

6.5 Distilled or deionized water in a squeeze wash bottle.

6.6 Kimwipes or equivalent lint-free tissue.

6.7 Flow cell; see Standard Practice for the Use of a Flow Cell for Field Measurements [LQ-10(T)].

## 7. Calibration

7.1 The following steps describe the calibration of the YSI Model 57 meter and the YSI 5739 probe in water-saturated air.

7.1.1 Adjust the mechanical ZERO with the instrument turned OFF.

7.1.2 Turn the control knob to the "red line" position and adjust if necessary.

7.1.3 Plug probe into instrument and wait about 15 minutes for the probe to polarize.

7.1.4 Turn the control knob to ZERO and adjust if necessary.

7.1.5 Turn the salinity knob to FRESH. A salinity correction will not be needed because the calibration is performed with distilled water.

7.1.6 Insert the probe about 4 centimeters (cm) into the open end of the bottomless plastic storage bottle containing a small sponge soaked with deionized water. Ensure that there is a tight fit between the probe and bottle and that there are no droplets of water on the probe membrane.

7.1.7 Allow at least 10 minutes for the system to reach constant temperature and 100 percent relative humidity. Be careful that this step is carried out in a constant temperature environment. Typically, bathe the bottle in a stream of the water to be tested or at least keep the bottle in the shade during equilibration.

7.1.8 Turn the meter control knob to TEMP position and read the temperature inside the bottle to the nearest 0.5 °C.

7.1.9 Determine the DO saturation value in parts per million (ppm) for that temperature from Table 1.

Table 1. Dissolved Oxygen Saturation Values at Various Temperatures

| Temp<br>(°C) | Sat.<br>Value<br>(ppm) | Temp<br>(°C) | Sat.<br>Value<br>(ppm) | Temp<br>(°C) | Sat.<br>Value<br>(ppm) | Temp<br>(°C) | Sat.<br>Value<br>(ppm) |
|--------------|------------------------|--------------|------------------------|--------------|------------------------|--------------|------------------------|
| 0            | 14.6                   | 12           | 10.8                   | 35           | 8.5                    | 36           | 7.0                    |
| 1            | 14.2                   | 13           | 10.6                   | 25           | 8.6                    | 37           | 6.8                    |
| 2            | 13.9                   | 14           | 10.4                   | 26           | 8.2                    | 38           | 6.7                    |
| 3            | 13.5                   | 15           | 10.2                   | 27           | 8.1                    | 39           | 6.6                    |
| 4            | 13.2                   | 16           | 9.9                    | 28           | 7.9                    | 40           | 6.5                    |
| 5            | 12.8                   | 17           | 9.7                    | 29           | 7.8                    | 41           | 6.4                    |
| 6            | 12.5                   | 18           | 9.5                    | 30           | 7.7                    | 42           | 6.3                    |
| 7            | 12.2                   | 19           | 9.3                    | 31           | 7.5                    | 43           | 6.2                    |
| 8            | 11.9                   | 20           | 9.2                    | 32           | 7.4                    | 44           | 6.1                    |
| 9            | 11.6                   | 21           | 9.0                    | 33           | 7.3                    | 45           | 6.0                    |
| 10           | 11.3                   | 22           | 8.8                    | 34           | 7.2                    |              |                        |
| 11           | 11.1                   | 23           | 8.7                    | 35           | 7.1                    |              |                        |

7.1.10 Determine the correction factor from Table 2 on the basis of either the atmospheric pressure (most accurate method) or the altitude above sea level. (Tables 1 and 2 are also available on the back of the YSI 57).

*Table 2. Correction Factors for Dissolved Oxygen Saturation Values as Determined by Pressure or Altitude*

| Pressure<br>(mm) | Altitude<br>(ft) | Correction<br>Factor |
|------------------|------------------|----------------------|
| 775              | -540             | 1.02                 |
| 760              | 0                | 1.00                 |
| 745              | 542              | 0.98                 |
| 730              | 1094             | 0.96                 |
| 714              | 1688             | 0.94                 |
| 699              | 2274             | 0.92                 |
| 684              | 2864             | 0.90                 |
| 669              | 3466             | 0.88                 |
| 654              | 4082             | 0.86                 |
| 638              | 4756             | 0.84                 |
| 623              | 5403             | 0.82                 |
| 608              | 6065             | 0.80                 |
| 593              | 6744             | 0.78                 |
| 578              | 7440             | 0.76                 |
| 562              | 8204             | 0.74                 |
| 547              | 8939             | 0.72                 |
| 532              | 9694             | 0.70                 |
| 517              | 10472            | 0.68                 |
| 502              | 11272            | 0.66                 |

7.11 Multiply the correction factor by the saturation value to obtain the calibration value.

7.12 Turn the meter control knob to the desired range and adjust the calibration knob to set the meter to the calibration value.

7.13 Perform zero oxygen check as follows. Prepare a solution containing 1 gram of sodium sulfite ( $\text{Na}_2\text{SO}_3$ ) and about 1 milligram of cobaltous chloride ( $\text{CoCl}_2$ ) in 1 liter of deionized water. Insert the probe into this solution and measure the dissolved oxygen. The instrument will read less than 0.2 milligram per liter (mg/L) if the probe is functioning properly.

**Caution:** These chemicals are toxic in the concentrated form. Avoid eye and skin contact by wearing eye protection and disposable gloves.

7.14 Leave the meter turned on during the entire day on which measurements are being taken.

## 8. Procedure

8.1 The following steps outline the field measurement of dissolved oxygen using the YSI Model 57.

8.1.1 Remove the probe from the storage bottle and place it in the solution to be measured. An in situ measurement is preferred. If the sample is being pumped from a well, the measurement shall be made in an air-exclusion cell.

8.1.2 Move the probe through the water or pump through a flow cell to ensure a velocity of at least 1 foot per second past the probe. This prevents depletion of oxygen at the membrane-water interface.

8.1.3 Turn the meter control knob to TEMP position and record the temperature to the nearest 0.5 °C.

8.1.4 Turn the meter control knob to the proper DO scale; after the meter reading has stabilized, record DO concentration to the nearest 0.1 mg/L.

8.1.5 Remove the probe, rinse with distilled water, blot dry, and return the probe to the storage bottle.

## 9. Quality Assurance

9.1 The following information about the field measurement of dissolved oxygen shall be logged for quality-assurance documentation:

9.1.1 Date and time zero check was last performed.

9.1.2 Atmospheric pressure or altitude.

9.1.3 Temperature of calibration chamber.

9.1.4 DO saturation from table.

9.1.5 Correction factor used for altitude or pressure.

9.1.6 Calibration value.



9.1.7 Sample temperature.

9.1.8 Measured DO.

9.1.9 Instrument manufacturer and model number.

9.1.10 Name of person performing the measurement.

## 10. Precision and Bias

10.1 Under normal conditions, precision and accuracy of  $\pm 0.5$  mg/L can be expected from this procedure.

## 11. Keywords

10.1 Altitude, atmospheric pressure, and dissolved oxygen.



# Standard Practice for the Use of a Flow Cell for Field Measurements

## Introduction

Reliable field measurements are an essential part of a groundwater sampling program. Some properties or constituents in groundwater may change considerably within a few minutes of collection. These changes are caused by turbulence, heating or cooling, depressurization, and gas exchange with the atmosphere. Use of a closed flow-through cell will minimize these changes.

### 1. Scope

1.1 This procedure describes the use of a closed flow-through cell for monitoring selected chemical parameters in groundwater. The cell is used when monitoring the purging of stagnant water from monitor wells before sample collection and for the measurement of pH, oxidation-reduction potential, conductivity, temperature, and dissolved oxygen under conditions as close to in situ as practical. A flow-through cell can be purchased from various suppliers or can be constructed as described in references 3.1 and 3.2.

### 2. Hazard Analysis

2.1 Refer to project safety plan for site- or task-specific hazards and control methods.

### 3. Referenced Documents

3.1 Garske, E., and R. Schock, "An Inexpensive Flow-Through Cell and Measurement System for Monitoring Selected Chemical Parameters in Ground Water", *Ground Water Monitoring Review*, Summer 1986

3.2 Korte, N., and D. Ealey, *Procedures for Field Chemical Analyses of Water Samples*, Technical Measurements Center, U.S. Department of Energy, Grand Junction Area Office, GJ/TMC-07(83), 1983

3.3 Wood, W.W., "Guidelines for Collection and Field Analysis of Ground-Water Samples for Selected Unstable Constituents", Chapter D2 in *Techniques of Water-Resources Investigations of the United States Geological Survey*, Book 1, 1976

### 4. Significance and Use

4.1 Flow cells allow the sampler to obtain test results that are more representative of conditions present in the water when it resided in the ground. That is, fewer chemical and physical changes occur if the test is made immediately through a flow cell than if the water is exposed to air and to a longer period of time before measurements are made.

### 5. Apparatus

5.1 Flow-through cell.

5.2 Stoppers, fittings, valves, and tubing, as required.

### 6. Procedure

6.1 Establish temperature equilibrium between the sample water and calibration solutions (solutions must be within  $\pm 10^{\circ}$  C of the sample temperature).

6.2 Calibrate the electrodes.

6.3 Connect the pump outlet to the inlet of the flow cell.

6.4 Insert the calibrated electrodes into the flow cell and connect tubing to the outlet of the flow cell.

6.5 Recheck electrode calibration as necessary during the purging of the well and just before sampling.

6.6 Turn off the pump, disconnect the tubing, and remove the electrodes from the flow cell.

6.7 Clean the flow cell with distilled water and prepare for sample collection.

## **7. Procedure Bias**

7.1 The flow rate through the cell shall not be more than 1 liter per minute (L/m). If flow rates exceed 1 L/m, streaming potentials could occur. Streaming potentials are caused by the static-charge effect of water moving through small openings. These potentials can cause erroneous pH readings. If necessary, reduce the flow rate or stop pumping to take readings.

7.2 The cell assembly, electrodes, and hoses should be insulated or kept out of direct sunlight to reduce the effect of temperature changes on the readings.

## **8. Quality Assurance**

8.1 The use of a closed flow-through cell should be noted on the sample documentation form or in the field logbook.

## **9. Keywords**

9.1 Chemical parameters, conductivity, dissolved oxygen, oxidation-reduction potential, flow cell, temperature, and pH.

Section A-10  
LQ-11(P)

# Standard Practice for the Sampling of Liquids

## Introduction

The type of sampling equipment shall depend on the sample to be collected, which analytes the sample is being collected for, and the site-specific requirements such as depth to water or depth of well. Because each sampling situation is unique, the equipment used and its application may have to be modified to ensure that a representative sample is collected and its physical and chemical integrity is maintained.

## 1. Scope

1.1 The procedures listed here are used to collect liquid samples. There are eight methods that can be used to collect liquid samples. Some sampling situations use a combination of these methods. For example, a peristaltic pump could be used to collect the inorganic samples and a bailer used to collect the organic samples. The eight methods are

|                                                                    | Section |
|--------------------------------------------------------------------|---------|
| Method A—Sampling With a Peristaltic Pump                          | 5-7     |
| Method B—Sampling With a Bladder Pump                              | 8-10    |
| Method C—Sampling With a Bailer                                    | 11-13   |
| Method D—Sampling With a Submersible Pump                          | 14-16   |
| Method E—Sampling With a Composite Liquid Waste Sampler (Coliwasa) | 17-19   |
| Method F—Sampling With a Dip-Type Sampler                          | 20-22   |
| Method G—Sampling by Container Immersion                           | 23-25   |
| Method H—Sampling From Taps, Valves, or Faucets                    | 26-28   |

## 2. Hazard Analysis

2.1 These procedures use gasoline-powered electric generators, gasoline-powered air compressors, and battery-powered pumps and accessories. The following safety precautions shall be followed.

2.1.1 Air compressors that are belt driven shall have a belt guard in place.

2.1.2 Care shall be taken when connecting and disconnecting equipment powered by lead-acid batteries to avoid generating sparks that have the potential of creating an explosive hazard.

2.1.3 Gasoline is a Department of Transportation-regulated material; its hazard class is Flammable Liquid. Gasoline shall be stored in Factory Mutual-approved safety cans. Safety cans shall be well secured in the vehicle during transport. Gasoline-powered equipment shall be cool before filling, and care should be taken not to spill any gasoline.

2.1.4 Air compressors shall not be operated above rated capacities and shall be configured to avoid having any dead-end fittings above 20 pounds per square inch (psi).

2.1.5 Care shall be taken when lifting heavy equipment; proper lifting techniques shall be used.

2.1.6 Site-specific controls are available in the planning documents for a particular site.

## 3. Referenced Documents

3.1 American Society for Testing and Materials, *Standard Guide for Sampling Groundwater Monitoring Wells*, D4448-S5a, 1986.

3.2 Geotech, *Environmental Procedures Catalog*, Manual 116:

Standard Practice for Sample Labeling [GN-8(P)].

Standard Practice for Equipment Decontamination [GN-13(P)].

General Considerations for the Sampling of Liquids [LQ-1(G)].

3.3 U.S. Department of Energy, *The Environmental Survey Manual*, Appendix E, Volume 4, DOE/EH-0053, 1987.

3.4 U.S. Environmental Protection Agency, *Handbook of Groundwater*, EPA/625/6-87/016, 1987.

3.5 U.S. Environmental Protection Agency, *Practical Guide for Groundwater Sampling*, EPA/600/2-85/104, 1985.

3.6 U.S. Environmental Protection Agency, *SW-846, Test Methods for Evaluating Solid Waste*, Volume 2, 1986.

#### 4. Significance and Use

4.1 The usefulness and limitations for each of the first four sampling methods are listed in General Considerations for the Sampling of Liquids [LQ-1(G)], Table 1 through Table 5. Coliwasa samplers are useful to obtain representative samples of multiphase materials from drums or other containerized vessels. Limitations are their relative high costs and the difficulty of decontaminating the sampler. Dip samplers only collect grab samples with a limited vertical extent. The sampler must be aware of this limitation and also exclude surface debris or films from liquid surfaces if this is not desired. Contamination from plumbing is a primary concern when sampling taps, valves, or faucets.

##### Method A

##### Sampling With a Peristaltic Pump

#### 5. Apparatus

- 5.1 Peristaltic-type pump.
- 5.2 Silicone, C-FLEX, or Norprene tubing for the pump head.
- 5.3 Silicone, Teflon, polyethylene, or vinyl tubing for placing in the liquid to be sampled (suction line).
- 5.4 Generator or other source of electricity.

#### 6. Procedure

6.1 The following procedure supplements the instruction in the instrument-specific operating manual.

6.1.1 Place the suction line in the liquid to be sampled. If sampling a monitoring well, place the tubing inlet just above the screened interval.

6.1.2 Connect the suction line to the pump.

6.1.3 Turn on the pump and adjust the flow rate so sample turbulence is at a minimum. Allow several liters to flow and recheck stability parameters (i.e., pH, conductivity, and temperature).

6.1.4 Fill the necessary sample bottles by allowing the pump discharge to flow gently down the side of the bottle with minimal turbulence.

6.1.5 Label, preserve, and document the samples as required by Standard Practice for Sample Labeling [GN-8(P)].

6.1.6 Remove the tubing from the liquid and clean and decontaminate as required by Standard Practice for Decontamination [GN-13(P)].

#### 7. Procedure Bias

7.1 Sampling organics using a peristaltic pump is not recommended. The suction lift action will strip volatiles and degas the sample. The silicone tubing tends to absorb some organics and slowly release them, contaminating subsequent samples.

##### Method B

##### Sampling With a Bladder Pump

#### 8. Apparatus

- 8.1 Bladder-type pump.
- 8.2 Air compressor.
- 8.3 Teflon, polyethylene, or vinyl tubing for the air and sample line.

#### 9. Procedure

9.1 The following procedure is supplemental to the instruction in the instrument-specific operating manual.

9.1.1 Lower the pump gently to a position just above the screened interval.

9.1.2 Connect the air line to the pump controller.

9.1.3 Initiate pumping and allow several liters of water to be pumped prior to sample collection (recheck stability parameters, i.e., pH, conductivity, and temperature).

9.1.4 Fill the necessary sample bottles by allowing the pump discharge to flow gently down the side of the bottle with minimal turbulence.

9.1.5 Label, preserve, and document the samples as required by Standard Practice for Sample Labeling [GN-8(P)].

9.1.6 Remove the pump from the well and clean and decontaminate as required by Standard Practice for Decontamination [GN-13(P)].

## 10. Procedure Bias

10.1 Bladder-type pumps constructed of stainless steel, Teflon, or both provide superior performance for most applications. The use of Teflon sample- and air-line tubing allows the bladder pump to be used for the collection of organics. The main disadvantage is the slow pumping rate, large consumption of compressed air, and difficulty in cleaning and decontaminating.

### Method C Sampling With a Bailer

## 11. Apparatus

- 11.1 Teflon or stainless steel bailer.
- 11.2 Teflon or stainless steel cable or line.
- 11.3 Bailer reel.

## 12. Procedure

- 12.1 Attach a properly cleaned bailer to the cable or line.
- 12.2 Lower the bailer slowly until it contacts the liquid.
- 12.3 Allow the bailer to sink until it reaches the screened interval of the well or the desired sampling point.
- 12.4 Slowly raise the bailer to the surface.
- 12.5 Tip the bailer or use a bottom-emptying device and fill a container to recheck the stability parameters (i.e., pH, conductivity, and temperature).
- 12.6 Repeat steps 12.2 through 12.5 as many times as necessary to fill the sample bottles.
- 12.7 Label, preserve, and document the samples as required by Standard Practice for Sample Labeling [GN-8(P)].
- 12.8 Clean and decontaminate the bailer as required by Standard Practice for Decontamination [GN-13(P)].

## 13. Procedure Bias

13.1 Bailers constructed of Teflon, stainless steel, or both provide adequate performance for most applications. Bailers expose part of the sample to the atmosphere during sample withdrawal and

should not be used to collect samples where contact with the atmosphere is important (i.e., field measurement of dissolved oxygen and Eh). A bottom-emptying device is recommended for the collection of volatile organics using a bailer.

### Method D Sampling With a Submersible Pump

## 14. Apparatus

- 14.1 Submersible-type pump.
- 14.2 Discharge tubing of vinyl, polyethylene, or Teflon.
- 14.3 Power source of generator or batteries.

## 15. Procedure

- 15.1 The following procedure is supplemental to the instructions provided in the instrument-specific operating manual.
  - 15.1.1 Set up the pump according to the operating manual.
  - 15.1.2 Gently lower the pump to a position just above the screened interval.
  - 15.1.3 Initiate pumping and allow several tubing volumes of liquid to be pumped prior to sample collection. Recheck stability parameters, (i.e., pH, conductivity, and temperature).
  - 15.1.4 Fill the necessary sample bottles by allowing the pump discharge to flow gently down the side of the bottle with minimal turbulence.
  - 15.1.5 Label, preserve, and document the samples as required by Standard Practice for Sample Labeling [GN-8(P)].
  - 15.1.6 Remove the pump and clean and decontaminate as required by Standard Practice for Decontamination [GN-13(P)].

## 16. Procedure Bias

16.1 Considerable sample agitation results when using a submersible pump. Submersible pumps are not recommended for the collection of dissolved gases, organics, or oxidation/reduction-sensitive samples. They also have a higher potential of sample contamination because of the construction material.



**Method E**  
**Sampling With a Coliwasa Sampler**

**17. Apparatus**

17.1 Coliwasa-type sampler constructed of stainless steel, Teflon, polyethylene, or glass.

17.2 Teflon, stainless steel, or nylon suspension line.

17.3 Disposable gloves.

17.4 Kimwipes or equivalent lint-free tissue.

**18. Procedure**

18.1 Slowly lower the sampler into the liquid to be sampled. Lower the sampler at a rate that permits the levels of liquid inside and outside the sample tube to be about the same.

18.2 When the sample interval has been reached, seat the bottom check valve.

18.3 Slowly withdraw the sampler with one hand while wiping the outside of the sampler using a disposable tissue.

18.4 Carefully discharge the sample into the sample container.

18.5 Repeat steps 18.1 through 18.4 as many times as necessary to fill all the sample bottles.

18.6 Label, preserve, and document the samples as required by Standard Practice for Sample Labeling [GN-8(P)].

18.7 Clean and decontaminate the sampler as required by Standard Practice for Decontamination [GN-13(P)].

**19. Procedure Bias**

19.1 The Coliwasa-type sampler is appropriate for collecting samples of containerized liquids. The material of construction should be considered for the particular type of liquid to be sampled. A Coliwasa sampler is also difficult to decontaminate adequately.

**Method F**  
**Sampling With a Dip-Type Sampler**

**20. Apparatus**

20.1 Dip-type sampler constructed of Teflon, stainless steel, polypropylene, or glass.

**21. Procedure**

21.1 Assemble the sampler.

21.2 Slowly submerge the sampler into the liquid to be sampled causing minimal surface disturbance.

21.3 Retrieve the sampler from the liquid causing minimal surface disturbance.

21.4 Slowly empty the sampler into the sample bottle allowing the sample to flow gently down the side of the bottle.

21.5 Repeat steps 21.2 through 21.4 as many times as necessary to fill all of the sample bottles.

21.6 Label, preserve, and document the samples as required by Standard Practice for Sample Labeling [GN-8(P)].

21.7 Clean and decontaminate the sampler as required by Standard Practice for Decontamination [GN-13(P)].

**22. Procedure Bias**

22.1 A dip-type sampler is appropriate for surface liquids such as ponds, open tanks, pits, lagoons, and sewers. It can only be used for a grab-type sample, and its material of construction shall be compatible with the liquid to be sampled and the analytes of interest.

**Method G**  
**Sampling by Container Immersion**

**23. Apparatus**

23.1 Sample container.

23.2 Disposable gloves.

23.3 Distilled or deionized water in a squeeze bottle.

23.4 Kimwipes or equivalent lint-free tissue.

## 24. Procedure

24.1 After putting on the appropriate gloves, submerge the sample bottle below the liquid surface. If the liquid is flowing, point the bottle upstream.

24.2 Allow the container to fill to the desired volume.

24.3 Remove the container, cap and rinse the container's outside surface with clean water, and dry with a tissue.

24.4 Label, preserve and document the sample as required by Standard Practice for Sample Labeling [GN-S(P)].

## 25. Procedure Bias

25.1 The container-immersion method can only be used to collect samples from shallow streams, near the shore of ponds or lakes, or from open-top containerized liquids. It can only be used for a grab-type sample and requires immersing the hands; it is not acceptable for highly polluted or hazardous liquids.

### Method H

#### Sampling From Taps, Valves, or Faucets

## 26. Apparatus

26.1 Distilled or deionized water in a squeeze bottle.

26.2 Kimwipes or equivalent lint-free tissue.

26.3 If the sample bottle cannot be placed under the tap, valve, or faucet, a hose or other device shall be attached to the outlet to allow the sample to be collected.

## 27. Procedure

27.1 Turn on the tap, valve, or faucet and allow sufficient liquid to flow to ensure that any rust or

residue is removed from the lines and that fresh liquid is flowing.

27.2 Remove the cap from the sample container and place the container under the source.

27.3 Fill the sample bottle to the desired volume.

27.4 Repeat steps 27.2 and 27.3 as many times as necessary to fill all of the sample containers.

27.5 Shut off the tap, valve, or faucet; clean the outside of the sample container using clean water and wipe dry.

27.6 Label, preserve, and document the sample as required by Standard Practice for Sample Labeling [GN-S(P)].

## 28. Procedure Bias

28.1 This procedure is used to collect grab-type samples from piped systems. Strainers, aerators, and hose attachments should be removed prior to sample collection. The material of construction for the piping system influences sample impurities and should be documented in the field logbook.

## 29. Quality Assurance

29.1 All of the methods listed above require the following information to be logged for quality-assurance documentation.

29.1.1 Date of sample collection.

29.1.2 Location of sample.

29.1.3 Sample number.

29.1.4 Type of sampling mechanism used.

29.1.5 Container type, size, and number of samples collected.

29.1.6 Preservatives used.

29.1.7 Signature of sampler.

## 30. Keywords

30.1 Bailer, coliwasa, liquid samples, sampler, and sampling.

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# Standard Practice for the Collection, Filtration, and Preservation of Liquid Samples

## 1. Scope

1.1 This procedure addresses the collection, filtration, and preservation of liquid samples. Section 7 gives the general collection procedures. Sections 8 and 9 are specific to the collection of organics. Section 10 provides the procedure for sample filtration. Section 11 provides guidelines for sample preservation. Table 1 summarizes the generally accepted bottle types, volume requirements, preservatives, and holding times for most analytes.

1.1.1 Improper filtration, preservation, or residence time before analysis may compromise sample integrity.

1.2 Many factors should be considered during the sample collection phase: bottle type, bottle size, preservation, sample filtration, holding time, and order of sample collection.

## 2. Hazard Analysis

2.1 This procedure uses a variety of chemicals for preserving the samples. The sampler shall have a copy of and review the Material Safety Data Sheets (MSDS) for each of the chemicals that will be used at a particular site. Most of the preservatives can be categorized as strong acids or strong bases.

2.2 The personal protective measures for strong acids (hydrochloric [HCl], nitric [HNO<sub>3</sub>], and sulfuric [H<sub>2</sub>SO<sub>4</sub>]) and strong bases (such as sodium hydroxide [NaOH]) are to avoid eye and skin contact and avoid breathing vapors by wearing eye protection and disposable gloves, providing adequate ventilation, and taking first aid measures to flush eyes or skin immediately with water for 15 minutes and contacting a physician.

2.3 Site-specific controls are available in the Health and Safety Plan for a particular project.

## 3. Referenced Documents

3.1 GJO *Environmental Procedures Catalog*, (GJO 6): Procedure GT-2(P), "Standard Practice for Sample Labeling"

3.2 U.S. Environmental Protection Agency, *Specifications and Guidance for Contaminant-Free Sample Containers*, Office of Solid Waste and Emergency Response, Washington, D.C., EPA/540/R93/051, NTIS stock number PB93/963316, December 1992

## 4. Terminology

4.1 *Meniscus*—The curved, upper surface of a liquid in a container.

4.2 *MSDS*—Material Safety Data Sheet. Printed material that provides descriptions of the properties, hazards, and health and safety considerations of a chemical or material; emergency measures in case of an accident; and instructions on the safe handling of the chemical or material.

4.3 *Organic*—A compound that contains carbon.

4.4 *Volatile*—A compound that readily evaporates at normal temperatures and pressures.

## 5. Significance and Use

5.1 The procedures listed here are general guidelines. Site-specific requirements vary and no one procedure will fit all situations. In many cases, the judgment of a well-trained, experienced team leader is required to make the necessary decisions in the field to obtain the best sample possible and meet all requirements.

## 6. Apparatus

6.1 Sample bottles

Table 1. Guidelines for Preservation of Samples

| Analytical Parameter                                                                      | Container Type/Size*                 | Preservation                                           | Holding Time                                                          |
|-------------------------------------------------------------------------------------------|--------------------------------------|--------------------------------------------------------|-----------------------------------------------------------------------|
| <b>Inorganic Anions</b>                                                                   |                                      |                                                        |                                                                       |
| Chloride (Cl), sulfate (SO <sub>4</sub> ), fluoride (F), bromide (Br), and orthophosphate | P/125 mL                             | Filtered 0.45 µm, cool to 4 °C                         | Cl, SO <sub>4</sub> , FL, Br -- 28 days<br>Orthophosphate -- 48 hours |
| Nitrate (NO <sub>3</sub> ), Nitrite (NO <sub>2</sub> )                                    | P/125 mL                             | Filtered 0.45 µm, cool to 4 °C                         | 48 hours                                                              |
| Nitrate (NO <sub>3</sub> and NO <sub>2</sub> as N)                                        | P/125 mL                             | Filtered 0.45 µm, H <sub>2</sub> SO <sub>4</sub> pH <2 | 28 days                                                               |
| Ammonia, NO <sub>3</sub> , NO <sub>2</sub>                                                | P/125 mL                             | Filtered 0.45 µm, H <sub>2</sub> SO <sub>4</sub> pH <2 | 28 days                                                               |
| Ammonium                                                                                  | P/125 mL                             | Filter, cool, H <sub>2</sub> SO <sub>4</sub> pH <2     | 28 days                                                               |
| <b>Inorganic Cations</b>                                                                  |                                      |                                                        |                                                                       |
| Dissolved metals                                                                          | PA/500 mL                            | Filtered 0.45 µm, HNO <sub>3</sub> pH <2               | 6 months (except mercury is 28 days)                                  |
| Total metals                                                                              | PA/500 mL                            | HNO <sub>3</sub> pH <2                                 | 6 months                                                              |
| <b>Radioisotopes</b>                                                                      |                                      |                                                        |                                                                       |
| Uranium-234/uranium-238                                                                   | P/1 L                                | Filtered 0.45 µm, HNO <sub>3</sub> pH <2               | 6 months                                                              |
| Thorium-230                                                                               | P/1 L                                | Filtered 0.45 µm, HNO <sub>3</sub> pH <2               | 6 months                                                              |
| Polonium-210                                                                              | P/1 L                                | Filtered 0.45 µm, HNO <sub>3</sub> pH <2               | 6 months                                                              |
| Lead-210                                                                                  | P/1 L                                | Filtered 0.45 µm, HNO <sub>3</sub> pH <2               | 6 months                                                              |
| Radium-226                                                                                | P/1 L                                | Filtered 0.45 µm, HNO <sub>3</sub> pH <2               | 6 months                                                              |
| Radium-228                                                                                | P/1 L, 3 each                        | Filtered 0.45 µm, HNO <sub>3</sub> pH <2               | 6 months                                                              |
| Gross alpha/beta                                                                          | P/1 L                                | Filtered 0.45 µm, HNO <sub>3</sub> pH <2               | 6 months                                                              |
| Radon                                                                                     | G/40 mL with Teflon spectra, 3 each  | Cool to 4 °C                                           | Not established; analyze ASAP                                         |
| <b>Organics</b>                                                                           |                                      |                                                        |                                                                       |
| Volatile organics                                                                         | GA/40 mL with Teflon spectra, 3 each | Cool to 4 °C, HCL pH <2                                | 14 days                                                               |
| Semivolatile organics                                                                     | GA/2.5 L with Teflon lined cap       | Cool to 4 °C                                           | 7 days extraction, 40 days analysis                                   |
| Polychlorinated biphenyls and pesticides                                                  | GA/1 L with Teflon lined cap         | Cool to 4 °C                                           | 7 days extraction, 40 days analysis                                   |
| Chlorinated herbicides                                                                    | GA/1 L with Teflon lined cap         | Cool to 4 °C                                           | 7 days extraction, 40 days analysis                                   |
| Total organic halides (TOX)                                                               | GA/1 L                               | Cool to 4 °C                                           | 28 days                                                               |
| Total organic carbon (TOC)                                                                | GA/125 mL                            | H <sub>2</sub> SO <sub>4</sub> pH <2, cool to 4 °C     | 28 days                                                               |
| Phenals                                                                                   | GA/1 L                               | H <sub>2</sub> SO <sub>4</sub> pH <2, cool to 4 °C     | 28 days                                                               |
| Oil and grease                                                                            | GA/1 L                               | H <sub>2</sub> SO <sub>4</sub> pH <2, cool to 4 °C     | 28 days                                                               |
| <b>Other</b>                                                                              |                                      |                                                        |                                                                       |
| Biochemical oxygen demand (BOD)                                                           | GA/1 L                               | Cool to 4 °C                                           | 48 hours                                                              |
| Chemical oxygen demand (COD)                                                              | GA/1 L                               | Cool to 4 °C, H <sub>2</sub> SO <sub>4</sub> pH <2     | 28 days                                                               |
| Total dissolved solids                                                                    | P/125 mL                             | Cool to 4 °C                                           | 7 days                                                                |
| Cyanide                                                                                   | P/1 L                                | NaOH pH >12, cool to 4 °C                              | 14 days                                                               |
| Sulfide                                                                                   | P/1 L                                | 2 mL zinc acetate, NaOH pH >9, cool to 4 °C            | 7 days                                                                |

\*P = polyethylene; G = glass; A = amber; mL = milliliter; L = liter.

Note: Amber container is not required for metals unless photosensitive metals (e.g., silver) are being analyzed.

## 6.2 Sample labels

6.3 Sample ticket books (GJPO 1854), example shown below.

| Analyte(s)       | Container Type | Number Collected | Filtered | Preservative                        |
|------------------|----------------|------------------|----------|-------------------------------------|
| Pb-226           | 1 Lb (pl)      | 2                | Y        | HNO <sub>3</sub> ; HCl <sup>2</sup> |
| Gross alpha      | 1 Lb (pl)      | 1                | Y        |                                     |
| Dissolved metals | 500 mL (pl)    | 1                | Y        |                                     |
| TDS              | 250 mL (pl)    | 1                | Y        | boiled, 4°C                         |
| Ammonia          | 125 mL (pl)    | 1                | Y        |                                     |

Figure 1. Example of a Sample Ticket (GJO 1854)

6.4 Water Sampling Field Data Sheet (GJO 1805), Figures 2a and 2b

6.5 Preservative solutions as required by the planning documents.

6.6 Dispensers for preservative solutions.

6.7 Coolers and ice for cooling collected samples.

6.8 In-line filter holders and filter sheets of 0.45 micrometer (μm) pore-size or in-line disposable 0.45-μm pore-size filters.

6.9 Pump and tubing

6.10 Distilled water and lint-free tissue

6.11 Project logbook

## 7. General Sample Collection Procedures

7.1 Collect all samples as close to the source as possible.

7.2 Choose the appropriate bottles for the analytes needed (see Table 1). Visually inspect the bottles for cleanliness, breaks, and missing parts prior to sampling. Sample bottles should be pre-cleaned to guidelines established by the U.S. Environmental Protection Agency (EPA) in reference 3.2.

7.3 Complete the sample ticket (Figure 1) and label the bottles as required by the planning documents or Standard Practice for Sample Labeling [GT-2(P)], reference 3.1.

7.4 Preservatives may be added at this time, or they may be added after sample collection. (Samples collected without headspace must be pre-preserved.)

7.5 Collect the samples by allowing the liquid to flow gently down the side of the bottle with minimal turbulence. Collect unfiltered samples prior to filtered samples.

7.6 Collect unfiltered samples in the following order:

7.6.1 Volatile organics and total organic halides

7.6.2 Dissolved gases and total organic carbon

7.6.3 Large-volume samples for organic compounds

7.6.4 Sensitive inorganics, such as nitrogen dioxide, ammonium, and ferrous oxide

7.6.5 Total metals


7.7 Collect filtered samples in the following order:

7.7.1 Alkalines

7.7.2 Trace metals

7.7.3 Major cations/anions

## Water Sampling Field Data

Date 3-18-99 Project Location LAKEVIEW Well / Location No. 504  
Sequence Number 18 Sample Number  NDG 597

### Well Purging Information

Depth to water 6.97 Casing Diameter 2"  
Depth of well 79.92 Casing Volume 1X 12 3X 36 10X (gal.) 2"=.163, 4"=.653gft  
Depth of water 72.95 Borehole Volume NA Low Flow Purge Volume NA  
Sampling Equipment Grundfos 12V Submersible Peristaltic Other: \_\_\_\_\_  
Measurement Equipment YSI 3500, Hach 2100P Turbidimeter, Hach alkalinity Other: \_\_\_\_\_

### Calibration Information

Conductivity  
Time of calibration check 0940 pH  
Temperature of calibration standard 6.7 Time of two-buffer calibration 0940  
Conductivity reading 661 Temperature of buffer solutions 6.7  
Conductivity reading at 25° C 1042 Buffers used for calibration 7, 10

### Turbidity

Time of operational check 0945  
Gelex Standards

| Assigned Value | Actual Reading |
|----------------|----------------|
| <u>5.30</u>    | <u>5.30</u>    |
| <u>61.6</u>    | <u>61.8</u>    |
| <u>574</u>     | <u>575</u>     |

### Dissolved Oxygen

Time of last check with NaSO<sub>3</sub> solution \_\_\_\_\_  
Atmospheric pressure \_\_\_\_\_ mmHg. Altitude \_\_\_\_\_  
Temperature of calibration chamber \_\_\_\_\_  
DO saturation \_\_\_\_\_  
Correction Factor \_\_\_\_\_  
Calibration Value \_\_\_\_\_

### Eh

Temperature of Zobell solution 0940  
Eh of Zobell solution 255 mV

### Final Sample Data

Measurement conditions: In situ ( ) Open container ( ) Air exclusion (X)

| Time        | Temp        | Conductivity | Conductivity ATC | pH          | Eh         | Turbidity   | D.O.      |
|-------------|-------------|--------------|------------------|-------------|------------|-------------|-----------|
| <u>1023</u> | <u>11.0</u> | <u>958</u>   | <u>1331</u>      | <u>7.42</u> | <u>-14</u> | <u>0.11</u> | <u>NA</u> |

### Alkalinity

Time 1027 Unfiltered Total alkalinity 108 ppm as CaCO<sub>3</sub>  
Time 1030 Filtered Total alkalinity 110 ppm as CaCO<sub>3</sub>

Hach kit method: Titration cartridge 1.6 NH<sub>4</sub>SO<sub>4</sub>

Phenolphthalein alkalinity (for pH 8.3 or greater) Unfiltered: NA Filtered: NA

### Filters

Number of 0.45  $\mu$  disposable filters used 1

Figure 2a. Example of a Water Sampling Field Data Sheet, Front (GJO 1805)



Grand Junction Office  
2597 B 3/4 Road  
P.O. Box 14000  
Grand Junction CO 81502

Sample Nu



Well / Location No.

504

Date 3-18-99

## Purge Data

[illegible]

Note: if low flow purging was performed, water level after optimizing pump rate NA and a final water level must be noted after purging is complete. WL NA Time NA

### Well Inspection

| Well Label | Guardposts | Concrete Pad | Protective casing | Riser Cap | Lock                  |
|------------|------------|--------------|-------------------|-----------|-----------------------|
| OK         | NA         | NA           | OK                | OK        | OK <sup>NO LOCK</sup> |

Sample Preservation: Is ice in cooler (YES) (NO) Weather: cloudy, cool

**Comments:**

**Signature of Sampler**

**Date Signed**

3-18-99

**Checked by**

**Date checked**

3/18/99

Figure 2b. Example of a Water Sampling Field Data Sheet, Back (GJO 1805)

#### 7.7.4 Radionuclides

7.8 Add preservative as required, if not pre-preserved.

7.9 Cap the bottle securely.

7.10 Store as required. Some samples may require storing at 4 °C immediately after collection. Use a cooler with ice for storing these samples.

7.11 Complete the Water Sampling Field Data Sheet (Figures 2a and 2b) as shown.

### 8. Nonvolatile Organics Sampling Procedure

8.1 Follow steps 7.1 through 7.3.

8.2 Add preservatives to the bottle, if required.

8.3 Collect samples for nonvolatile organics by slowly filling the bottle, allowing the liquid to flow gently down the side of the bottle with minimal turbulence. Do not filter samples to be analyzed for organics.

8.4 Cap the bottle securely.

8.5 Store as required. Most organic samples require storage at 4 °C.

### 9. Volatile Organics Sampling Procedure

9.1 Take special care when collecting a volatile organic sample to reduce the possibility of losing the volatile constituents. Volatile organics are collected in a 40-milliliter (mL) glass vial that has a Teflon-lined, silicone-septum cap.

9.2 Label the vial.

9.3 Add preservative (if required).

9.4 Slowly fill the vial to overflowing.

9.5 Hold the vial level or carefully set it on a level surface.

9.6 Place the cap with septum, Teflon-side down on the convex water meniscus and seal by screwing the cap to the bottle.

9.7 Check for air bubbles by inverting the vial and lightly tapping. There can be no air bubbles entrapped in the sample. If bubbles are present, uncapped the vial, empty the contents, and repeat steps 9.3 through 9.7.

### 10. Sample Filtration Procedure

10.1 Collect samples requiring filtration after unfiltered samples. If a pump is used, connect an in-line membrane filter directly to the pump outlet to filter the sample. If a bailer is used, connect the filter to the portable pump and pump the sample from the bailer or a clean sample bottle.

10.2 Start the pump and discard the first 100 mL of sample to flush the filter.

10.3 Place the sample bottle directly under the filter outlet and fill to the desired volume.

10.4 Preserve the sample (if not pre-preserved), as required.

10.5 Stop the pump, and disconnect the filter.

10.6 Discard the used filter after each sample. If a filter holder is used, clean all surfaces of the filter holder with distilled water and wipe dry with a lint-free tissue.

10.7 If a filter holder is used, place a new filter in the holder and reassemble.

### 11. Sample Preservation Guidelines

11.1 Samples are preserved by a variety of means to stabilize specific parameters so that the samples can be shipped to a laboratory for analysis. Preservatives are intended to (1) retard biological effects, (2) retard hydrolysis, (3) reduce sorption effects, and (4) reduce volatility of constituents.

11.2 Preservation methods are generally limited to pH control, chemical addition, refrigeration,

and protection from light. The following guidelines shall be considered during sample preservation.

11.2.1 Preservation of samples uses a variety of strong acids and bases. Care shall be taken in their storage and use; see section 2.

11.2.2 Preserve samples prior to or as soon after collection as possible.

11.2.3 Take care not to cross-contaminate samples with preservatives.

11.2.4 Place samples requiring cooling to 4 °C in an ice chest with ice immediately after collection.

11.2.5 Consult Table 1 or the planning documents for recommended sample preservation techniques for each parameter. Generally, the laboratory performing the analysis will determine the bottle type, volume, and preservative to be used for a particular sampling event.

## 12. Quality Assurance

12.1 In the sample ticket book (Figure 1) or Water Sampling Field Data Sheet (Figures 2a and 2b), record the following information about the sample collection, filtration, and preservation for quality-assurance documentation.

12.1.1 The number and type of filter used for filtration.

12.1.2 The bottle size, bottle type, and number of samples collected.

12.1.3 The type of sample filtration, if any.

12.1.4 The preservative used.

12.1.5 The name of the person performing the sampling.

## 13. Keywords

13.1 Bottles, collection, filtration, liquid samples, organics, and preservation

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Section A-12  
LC-18(P)

## Environmental Procedures Catalog Document Addition/Revision

**Procedure Title:** Standard Practice for Inspection and Maintenance of Groundwater Monitoring Wells, [LQ-18(P)], Rev. 1, 6/92

**Requester:** Tim Bartlett, Field Supervisor

**Justification:** The Well Maintenance Checklist form has been revised to allow multiple inspections and water-level measurements. An electronic data entry device has been purchased for project use. Subsurface inspection of inactive wells is not required because redevelopment of an idle well is not appropriate. If a well is changed from inactive to active status, the total depth will be measured and the redevelopment criteria will apply.

**Proposed Change:** Sections 5.1 and 6.2.1 - The Well Maintenance Checklist is replaced by the Water Level and Well Maintenance Data Sheet (attached) in the Water Sampling Field Data book. Section 6.2.1 - Inspection information will be entered into an electronic hand-held data entry device. The Water Level and Well Maintenance Data Sheet will be used as a back-up method for data entry. Section 6.2.3 - Total depths will be measured only on active wells (wells that are sampled or have water level measured). Wells with dedicated pump installations will not have total depth measured.

---

### Authorization for Changes to Catalog Procedures

☐ New Document

☐ Change to Existing Procedure

☐ Adopt Procedure

Procedure Number Assigned \_\_\_\_\_

Procedure Title \_\_\_\_\_

Approval for Inclusion in Environmental Procedures Catalog:

\_\_\_\_\_  
Environmental Procedures Advisory Committee Chair

\_\_\_\_\_  
Date

---

### Authorization for Project Specific Modification to Existing Catalog Procedures

Project Specific Change for MMTS Operable Unit III, Interim Remedial Action Surface Water and Ground Water Monitoring Program (MAC-MSGRAP 1.3.5-2)

Effective Date April 5, 1999

Reviewed By [Signature]  
Technical Author or  
Proficient Designee

4/1/99  
Date

Approved By [Signature]  
Manager or Designee

4/1/99  
Date

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## MONTICELLO WELL MAINTENANCE DATA SHEET

Well Identification \_\_\_\_\_

N. \_\_\_\_\_ E. \_\_\_\_\_

Measuring Point \_\_\_\_\_

Measuring Point Elevation \_\_\_\_\_

Reported Depth \_\_\_\_\_

Dedicated Pump Installed \_\_\_\_\_

| Date | Subsurface Inspection |                      |                   | Surface Components Inspection |             |      |                   |     | Technician Initials | Comments |           |
|------|-----------------------|----------------------|-------------------|-------------------------------|-------------|------|-------------------|-----|---------------------|----------|-----------|
|      | Measuring Device      | Depth to Water (ft.) | Total Depth (ft.) | Well Label                    | Guard-posts | Lock | Protective Casing | Pad |                     |          | Riser Cap |
|      |                       |                      |                   |                               |             |      |                   |     |                     |          |           |
|      |                       |                      |                   |                               |             |      |                   |     |                     |          |           |
|      |                       |                      |                   |                               |             |      |                   |     |                     |          |           |
|      |                       |                      |                   |                               |             |      |                   |     |                     |          |           |
|      |                       |                      |                   |                               |             |      |                   |     |                     |          |           |
|      |                       |                      |                   |                               |             |      |                   |     |                     |          |           |
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Surface Components Inspection:    S - Satisfactory  
                                                       D - Deficient



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# Standard Practice for the Inspection and Maintenance of Groundwater Monitoring Wells

## Introduction

Groundwater monitoring wells are commonly used for obtaining groundwater samples, groundwater elevation measurements, and aquifer hydraulic parameters. Because of natural processes and human activities, the condition of groundwater monitoring wells may deteriorate with time. If the deterioration of a particular monitoring well is not documented and corrected, decisions based upon data collected from that well may be adversely affected. This procedure provides a standard practice for maintaining a record of the condition of a well and remediating wells that have deteriorated.

### 1. Scope

1.1 This procedure describes the standard practice for conducting routine inspections of groundwater monitoring wells. The procedure also provides criteria to use in determining if and when a monitoring well should receive corrective maintenance. Corrective maintenance activities are based on the results of the routine inspections. Lastly, this procedure describes the standard practices for conducting well maintenance. Well maintenance includes correcting deficiencies in the surface components of the well and redeveloping the well.

1.2 This procedure shall be applied only to groundwater monitoring wells. Groundwater production wells, used for water supply, are beyond the scope of this procedure. Because of the limitations associated with the redevelopment methods described in this procedure, the redevelopment section is not applicable to wells exceeding 6 inches in diameter. This procedure shall not be applied to multi-port, single-string monitoring wells.

1.3 This procedure shall be executed by a designated well-maintenance technician on all monitoring wells under the control of Geotech. At the discretion of the Project Manager and appropriate regulatory agencies, inactive monitoring wells may be excluded from redevelopment activities. This procedure should be performed quarterly, unless the Project Manager specifies a different frequency. At the discretion of the Project Manager, the procedure may be implemented in conjunction with routine groundwater sampling and data collection activities. In such a case, the inspection portion of the procedure shall be conducted prior to groundwater sampling and other data collection activities. All well-maintenance activities shall be conducted after groundwater sampling activities to eliminate

the potential for contaminating samples or altering the chemistry of groundwater samples.

### 2. Hazard Analysis

2.1 This procedure may involve the use of methanol for decontaminating water-level measurement devices and well redevelopment equipment. Methanol is a Department of Transportation (DOT)-regulated material; the DOT hazard class is Flammable Liquid. Methanol is also an Occupational Safety and Health Administration (OSHA)-listed toxic and hazardous substance. Avoid eye and skin contact by wearing indirectly vented chemical goggles and disposable nitrile gloves. Avoid breathing vapors. Use only in well-ventilated areas. Keep away from heat, sparks, and flames.

2.2 Monitoring wells that penetrate contaminated subsurface environments may contain toxic or hazardous vapors at pressures exceeding atmospheric pressure. These vapors can be expelled from the well bore when the riser cap is removed. If a well penetrates highly contaminated subsurface materials or groundwater, the off-gassing of vapors could continue for an extended period of time. If previous air-monitoring data have shown that the concentration of organic vapors exceeds the action level specified in the project Health and Safety Plan, respirators with combination organic/particulate cartridges shall be worn prior to the opening of the well. The respirators shall continue to be worn throughout the rest of the procedure or until current air-monitoring data indicate organic vapor concentrations have dropped below the action level. For all other wells, stand upwind of the well when removing the riser cap and performing inspection and maintenance activities. Allow the well riser to ventilate for 5 minutes after

opening before initiating inspection and maintenance activities. If the degree of contamination at the well site is unknown, or if the well has never been monitored for vapors by Geotech personnel, the air in the well bore shall be checked for the presence of volatile organic vapors prior to continuing with the procedure. Use a calibrated organic vapor analyzer (OVA) or photoionization detector (PID) to measure the total concentration of organic vapors. If the concentration indicated on the OVA (or PID) exceeds the action level specified in the project Health and Safety Plan, allow off-gassing to continue until the OVA (or PID) indicates that the concentration has dropped below the action level. If the concentration continues to exceed the action level, respirators with combination organic/particulate cartridges shall be worn during the inspection and maintenance procedure.

2.3 This procedure may involve the use of compressed nitrogen gas for redeveloping monitoring wells. Compressed nitrogen is supplied in steel tanks and injected into the well through a regulator, a flexible hose, and a series of threaded polyvinyl chloride (PVC) pipes. Improper use of equipment or failure of equipment could cause an explosive rupture of the redevelopment apparatus. Safety glasses, a hard hat, and steel-toed safety shoes shall be worn at all times when using a compressed nitrogen apparatus for the redevelopment of monitoring wells. Because the valve on a compressed nitrogen bottle is susceptible to breakage, the valve cover shall be screwed tightly in place during transport in vehicles, transport on hand trucks, or manual transport by well maintenance personnel. Additionally, the line pressure set on the regulator shall not be set in excess of 50 percent of the minimum-rated bursting pressure of either the flexible hose or the PVC pipe.

### 3. Referenced Document

3.1 Geotech, *Environmental Procedures Catalog* (Manual 116):

Standard Test Method for the Measurement of Water Levels in Groundwater Monitoring Wells [LQ-2(T)].

### 4. Significance and Use

4.1 *Significance* — Application of this practice will prevent most forms of degradation in monitoring wells. Application of this procedure will prevent the undetected contamination of monitoring

wells by infiltrating surface water and ensure a long service life for monitoring well installations.

4.2 *Use* — This procedure shall be used to (1) maintain an ongoing permanent record that documents the condition of groundwater monitoring wells, (2) identify when monitoring wells require maintenance, and (3) specify the procedures that shall be used to conduct monitoring-well maintenance. The procedure shall be implemented on a quarterly basis by a well-maintenance technician. Each time the inspection portion of the procedure is executed, the Well Maintenance Checklist (Figure 1) shall be completed and filed in the Project Well Maintenance File by the well-maintenance technician. At the discretion of the Project Manager, the procedure may be implemented more or less frequently, and the procedure may be executed by a groundwater sampling team. If the procedure is executed by a sampling team, the inspection portion of the procedure shall be performed prior to sampling a well. Any required maintenance activities shall be performed after sampling a well. This procedure shall not be applied to water-supply wells. Application of this procedure shall be limited to monitoring wells 6 inches in diameter or less.

### 5. Apparatus

- 5.1 Well Maintenance Checklist (Figure 1).
- 5.2 Electric water-level sounder.
- 5.3 Interface probe (optional).
- 5.4 Calibrated organic vapor analyzer or photoionization detector (optional).
- 5.5 Safety glasses.
- 5.6 Indirectly vented chemical goggles.
- 5.7 Nitrile gloves.
- 5.8 Respirator with combination organic/particulate cartridges.
- 5.9 Steel-toed safety shoes.
- 5.10 Hard hat (optional).
- 5.11 Laboratory-grade methanol in a squeeze wash bottle or pump spray canister.
- 5.12 Alconox or equivalent.
- 5.13 Distilled or deionized water in a squeeze wash bottle or pump spray canister.
- 5.14 Kimwipe or equivalent lint-free tissue.

### Well Maintenance Checklist

Site Identification \_\_\_\_\_ Well Number \_\_\_\_\_

Date \_\_\_\_\_ Field Technician \_\_\_\_\_

| Surface Components Inspection                         | (circle one) | Action Required/Taken |     |          |
|-------------------------------------------------------|--------------|-----------------------|-----|----------|
| Lock Working                                          | Yes No _____ |                       |     |          |
| Cap on Surface Casing Present                         | Yes No _____ |                       |     |          |
| Surface Casing Intact                                 | Yes No _____ |                       |     |          |
| Riser Cap Present                                     | Yes No _____ |                       |     |          |
| Guard Posts Adequately Painted<br>for High Visibility | Yes No _____ |                       |     |          |
| Concrete Surface Pad Present                          | Yes No       | Intact                | Yes | No _____ |
| Well Clearly and Correctly Numbered                   | Yes No _____ |                       |     |          |
| Organic Vapor Monitoring Conducted                    | Yes No _____ |                       |     |          |

| Subsurface Inspection                                            | Upper or Single<br>Completion | Middle<br>Completion | Lower<br>Completion |
|------------------------------------------------------------------|-------------------------------|----------------------|---------------------|
| Reported Depth of Well<br>(below top of casing)                  | _____                         | _____                | _____               |
| Reported Bottom of<br>Screened Interval<br>(below top of casing) | _____                         | _____                | _____               |
| Static Depth to LNAPL<br>(below top of casing)                   | _____                         | _____                | _____               |
| Static Depth to Water<br>(below top of casing)                   | _____                         | _____                | _____               |
| Static Depth to DNAPL<br>(below top of casing)                   | _____                         | _____                | _____               |

Redevelop if measured well depth is less than or equal to depth of bottom of screened interval.

Redevelopment Conducted Yes No Method Used \_\_\_\_\_

Comments/Recommendations \_\_\_\_\_

\_\_\_\_\_

Completed by \_\_\_\_\_ Verified by \_\_\_\_\_

Figure 1. Well Maintenance Checklist

5.15 Measuring tape with engineering scale (required if graduations on water-level sounder or interface probe are greater than 0.01 foot).

5.16 Compressed-nitrogen tank (required when using compressed nitrogen).

5.17 Compressed-gas regulator (required when using compressed nitrogen).



5.18 Nitrogen-jetting well-head apparatus (required when using compressed nitrogen).

5.19 Flexible compressed-gas transmission hose (required when using compressed nitrogen).

5.20 Threaded PVC pipe (required when using compressed nitrogen).

5.21 Jetting-T (required when using compressed nitrogen).

5.22 Submersible pump (optional).

5.23 Suction-lift pump (optional).

5.24 Surge block (optional).

5.25 PVC hose (optional).

5.26 Foot valve (optional).

5.27 High-visibility spray paint.

5.28 Steel stamp (for numbering wells).

5.29 Black permanent marking pen.

5.30 Black ink pen.

5.31 Well-location map.

## 6. Procedures

6.1 This procedure is composed of three sections: Section 6.2, Inspection and Documentation; Section 6.3, Maintenance Criteria and Corrective Action; and 6.4, Redevelopment Procedures.

### 6.2 Inspection and Documentation

6.2.1 Each item on the Well Maintenance Checklist shall be completed as the inspection is conducted. Corrective action to eliminate deficient aspects of a well installation is described in section 6.3. For multi-completion monitoring wells (multiple-well casings in a single borehole), a single Well Maintenance Checklist shall be completed for a group of completions in a common borehole.

6.2.2 *Surface Components Inspection* —The first step of the inspection is to inspect the above-ground components of a monitoring-well installation. Some surface components identified in this section of the procedure are optional and will not be required at each well installation. An example is guard posts. The Project Manager and well-maintenance technician shall determine which components are required.

6.2.1.1 Check for presence of a lid on the steel security casing. If damaged, describe damage in "Comments/Recommendations" section of the Well Maintenance Checklist.

6.2.1.2 Check the lock on the steel security casing for proper operation.

6.2.1.3 Inspect the steel security casing for damage. If a drain or vent hole is present in the security casing, check to ensure that it is not plugged with debris. Clean the hole if necessary.

6.2.1.4 Check for presence of a casing-riser cap. If the well is a flush-mount well, note whether the casing-riser cap is a water-tight cap, slip-on cap, or a threaded cap.

6.2.1.5 Inspect the casing riser for damage. No contamination should be able to enter the well through openings in the side of the casing riser. Note that some casing risers have a "weep" hole drilled just below the riser cap. This hole allows air pressure in the well to equilibrate with atmospheric pressure as water levels or the atmospheric pressure fluctuates. This weep hole should not be closed. If the well is a flush-mount installation and the riser has a weep hole, note this fact in the "Comments/Recommendations" section of the Well Maintenance Checklist. Weep holes are generally not recommended for flush-mount wells as they permit liquids to enter the well if the flush-mount vault becomes flooded. Weep holes in the risers of flush-mount wells are permissible if the vault of the flush-mount installation has been installed to permit drainage from the vault or the vault has a water-tight cover.

6.2.1.6 Check for the presence of guard posts. If present, note whether guard posts are adequately painted for high visibility. If guard posts are not present, note this on the Well Maintenance Checklist.

6.2.1.7 Check for the presence of a concrete surface pad surrounding the security casing. If the concrete surface pad is absent or damaged, note this information on the Well Maintenance Checklist.

6.2.1.8 Check the well number or well identification to determine if it is clearly marked and in agreement with the well location map.

6.2.2 *Subsurface Inspection* —The second step of the inspection is to determine the subsurface condition of the well. This includes measuring the depth

to water and the depth to the bottom of the well. The measured depth to the bottom of the well, when compared to the recorded well depth and screened interval depth, will indicate the amount of sediment in the well. If sediment has accumulated to a level above the bottom of the screened interval, the well should be redeveloped. If a well is located near storage tanks or transmission lines that contain fuels, solvents, or other immiscible organic liquids, liquid levels in wells should be measured with an interface probe that is capable of detecting light non-aqueous-phase liquids (LNAPLs or floaters), water, and dense non-aqueous-phase liquids (DNAPLs or sinkers). The procedure for measuring liquid levels in wells is described in Standard Test Method for the Measurement of Water Levels in Groundwater Monitoring Wells [LQ-2(T)]. Nitrile gloves should be worn when conducting the subsurface inspection on wells with organic contaminants in the groundwater.

6.2.2.1 Record the reported depth of the well on the checklist (this can be done prior to departing for a field site). The depth should be recorded to the nearest 0.01 foot below the top of the casing.

6.2.2.2 Record the reported depth to the bottom of the screened interval (this can be done prior to departing for a field site). The depth should be recorded to the nearest 0.01 foot below the top of the casing.

6.2.2.3 If previous air-monitoring data have shown organic vapor concentrations that exceed action levels specified in the project Health and Safety Plan, respirators with combination organic/particulate cartridges shall be worn during the procedure. If the well head has never been monitored for organic vapors, or if there are other reasons to suspect severe organic chemical contamination in the subsurface near the well, the off-gases escaping from the well head should be monitored with an OVA or PID prior to making measurements. In such a case, the OVA or PID shall be calibrated each day prior to use. The casing-riser cap shall be removed and the well allowed to ventilate for 5 minutes. If the well is a flush-mount installation, all water standing in the vault shall be bailed prior to removing the riser cap. Place the intake nozzle of the OVA or PID just inside the well bore. Note the reading on the checklist. If the reading exceeds the action level specified

in the project Health and Safety Plan, allow the well head to continue off-gassing for several minutes and then repeat the OVA or PID measurement. Record the reading on the checklist. Once the OVA or PID indicates the concentration is less than the action level, proceed with the inspection procedure. If the organic vapor concentration does not drop below the action level, respirators with combination organic/particulate cartridges shall be worn for the remainder of work performed at the well. If the air contained in the well bore is known to contain no toxic vapors, no OVA or PID measurement is required.

6.2.2.4 Clean the water-level sounder or interface probe prior to inserting in the well, following the procedure presented in Standard Test Method for the Measurement of Water Levels in Groundwater Monitoring Wells [LQ-2(T)].

6.2.2.5 Measure the depth to water to the nearest 0.01 foot and record on the checklist. The depth shall be measured from the top of the casing riser; see Standard Test Method for the Measurement of Water Levels in Groundwater Monitoring Wells [LQ-2(T)]. If the well has contained NAPLs in the past, if it is located near NAPL storage or transmission equipment, or if the OVA or PID reading was unusually high, an interface probe should be used to measure an LNAPL-air interface depth, an LNAPL-water interface depth, and a water-DNAPL interface depth. On the Well Maintenance Checklist record the depth to the air-LNAPL interface after "Static Depth to LNAPL," record the depth to the LNAPL-water interface after "Static Depth to Water," and record the depth to the water-DNAPL interface after "Static Depth to DNAPL."

6.2.2.6 Measure the total depth of the well by gently lowering the probe to the bottom of the well. After the probe reaches the well bottom, slowly raise and lower it several times to accurately determine the depth to the top of any sediment column that may have accumulated in the well. Record the depth to the nearest 0.01 foot on the Well Maintenance Checklist.

6.2.2.7 Use lint-free tissue, methanol (if organic contaminants are known or suspected to be present in the groundwater), and distilled or deionized water to clean the cable as it is removed from the well. The cable should first be cleaned with



methanol (if necessary), followed by deionized or distilled water. When the probe is removed from the well, rinse it first with methanol (if necessary), then deionized or distilled water. Wipe the probe dry with a lint-free tissue. If non-aqueous-phase liquids are present in a well, the cable and probe should be cleaned with Alconox (or equivalent) prior to cleaning with methanol and deionized water. During decontamination, care should be taken to prevent methanol or wash water from dripping into the well.

### 6.3 Maintenance Criteria and Corrective Action

6.3.1 This section describes criteria used to evaluate the conformance or nonconformance aspects of each component of the well inspection. For each nonconformance criteria, a corrective action is described. Whenever possible, corrective action should be implemented during the same field trip during which a nonconformance aspect was identified. Any corrective action taken should be noted on the Well Maintenance Checklist.

6.3.2 If the lid on the security casing is missing or damaged to the point of permitting access to the well, arrange a temporary cover, if possible, and make arrangements to have a new lid fixed to the security casing (commonly by welding).

6.3.3 If the lock on the steel security casing is missing, it should be replaced. If all monitoring-well locks currently in use at a site are keyed identically, a similarly keyed lock should be used to replace a missing one. However, if a lock of the same key type as other security casing locks is not immediately available, any strong lock should be installed for temporary well protection. In such a case, note the need for a new lock on the checklist. If a lock has become difficult to operate because of exposure, two or three drops of lubricant should be added to the tumbler assembly. **Do not over-lubricate or use sprays** as these actions will give rise to contamination of the well or sampling equipment that will be used at the well in the future. Note all corrective action on the checklist.

6.3.4 If the entire steel security casing is missing, make arrangements to replace it. The bottom of the security casing should be set 3 feet below the ground surface in concrete. The concrete should extend to the surface and be sloped away from the well. Repairs should be made if the security casing is in place but is damaged and allows liquids to

drain into the annular space around the well casing or is preventing proper access to the well. If repairs cannot be made, the need for these should be noted on the checklist.

6.3.5 If the casing-riser cap is missing, replace it. If the well is not a flush-mount well and the casing riser does not have a small drilled hole just below the cap, the riser cap should not be installed in an air-tight manner. If the well is a flush-mount well, the riser cap should be a water-tight cap. The water-tight cap should be installed securely in the well to prevent liquids that collect in the vault from entering the well casing. Flush-mount wells with vaults that permit drainage from the vault or those with water-tight vault lids do not need water-tight riser caps.

6.3.6 If the casing riser is damaged to the extent that standing liquids inside the security casing can enter the well, the damaged section should be cut off below the point of breakage. A new section of casing riser should then be tapped to accept a tapered stainless-steel male/male threaded pipe coupling. The top of the cut casing is then also tapped, and the coupling is wrapped with Teflon pipe tape. The coupling is then screwed into the new riser extension, and this assembly is screwed into the top of the cut casing riser. The new riser should have a weep hole drilled in it just below the cap to allow air pressure equilibration within the well bore. Care should be taken to ensure that the new casing riser is fitted with a casing-riser cap. This corrective action should be noted on the checklist and the well should be scheduled for a new elevation survey.

6.3.7 If the well is not a flush-mount installation and is in a location subject to equipment or vehicle traffic, guard posts should be present. If guard posts are not present but are needed, make arrangements for installation as soon as possible. To be effective, three guard posts should be installed in the shape of an equilateral triangle centered at the well with each post 2 to 3 feet from the well. The guard posts should be painted with a highly visible paint, such as Day-Glo orange or safety yellow. Approval of the manager of the site should be obtained prior to installing and painting guard posts.

6.3.8 If the concrete surface pad is damaged or is missing, a new concrete surface pad should be installed or arrangements should be made for the installation of a concrete surface pad. The pad

should extend 1 foot below the ground surface and 3 feet horizontally from the security casing. The pad should be sloped away from the well.

6.3.9 If the well is not numbered or marked with a well identification label, or if the number on the well does not match the well location map, a correct well identification number must be marked on the well. First, the correct well identification must be conclusively determined. This can be done by (1) consulting the well location map, if it has been certified to be correct; (2) consulting original field logs and completion records relating to the well's installation; and (3) consulting logs from other previous field activities such as sampling, episodes, and water-level measurements. Project personnel may also be interviewed in an effort to establish well identification. Once the identity of the well has been conclusively established, the well should be labeled with this number using a permanent method. Stamping the well identifier into the steel security casing with a steel stamp is recommended. The identifier should be stamped in the lid on the security casing and on the security casing itself, just below the lock. The identifier should also be written on the bottom-side of the security casing lid using a permanent ink pen. Multiple-completion wells should have the top of each riser cap marked with a letter designating the completion, such as "U" and "L" for "upper" and "lower," respectively. The casing risers in a multiple-completion well should then be marked in a similar manner. Take care to ensure that the label on the casing riser is below the position occupied by the cap or the weep hole, if present.

#### 6.4 Redevelopment Procedures

6.4.1 Monitoring wells shall be redeveloped if the well-inspection procedure indicates that excessive sedimentation is occurring, if the capacity of the well appears to have significantly declined during the course of a sampling program, if there is evidence of screen encrustation or clogging by iron bacteria, or if the well is simply scheduled for regular redevelopment.

6.4.2 Possible redevelopment techniques include (1) compressed-nitrogen-jetting and air-lift pumping, (2) surge-blocking and pumping or bailing, (3) suction-lift pumping, (4) submersible pumping, and (5) foot-valve pumping.

6.4.3 Successful redevelopment requires that water be forced from the casing into the formation, and from the formation into the casing. This is best

accomplished through the use of a surge block. Compressed-nitrogen jetting can also accomplish this flow reversal to some extent. Techniques 3, 4, and 5 (above) are not effective in achieving flow reversal and are, therefore, best used in conjunction with nitrogen jetting or surge blocking.

6.4.4 Prior to placing any redevelopment equipment in a monitoring well, the equipment shall be cleaned by washing with soapy water (Alconox or equivalent), rinsing with methanol followed by deionized water, and wiping dry with a lint-free tissue. After removing redevelopment equipment from a well, the equipment shall be cleaned again. Methanol should only be used for cleaning after redevelopment if organic contamination is suspected or known to be present in the well. Alconox should only be used if the well is suspected or known to contain non-aqueous-phase liquids (fuels and/or solvents).

#### 6.4.5 Nitrogen-Jetting Redevelopment Procedure

6.4.5.1 If site conditions require that purge water from the well be contained, a discharge-control apparatus should be installed on the well riser. This apparatus typically consists of a compression-sleeve coupling with a discharge port that is connected to the well riser. A compression-type seal for the jetting pipe is rigged at the top of the discharge-control apparatus. Even if site regulations do not require discharge water to be collected and stored, a discharge-control apparatus should be used at sites that may have contaminated groundwater. Use of the discharge-control apparatus will prevent the splashing of discharge water on well-maintenance technicians.

6.4.5.2 A jetting-T is connected to a series of PVC pipes (the jetting pipe) and lowered to the top of the screened interval. The top of the jetting pipe is then connected to a compressed nitrogen source via a flexible compressed gas transmission hose. The flexible hose is connected to a two-stage regulator on the nitrogen source. The first stage of the regulator displays the pressure in the nitrogen tank. The second stage displays the pressure at the flexible hose when the regulator is opened. To prevent injury caused by the nitrogen tank falling over, the tank must be either secured in an upright position with a chain or placed on its side and secured by wheel chocks.

6.4.5.3 Set the line pressure on the regulator at a maximum of 60 pounds per square inch (psi). Jet the well screen by quickly opening the line valve,

allowing the water to rise in the well, and then closing the line valve. As air (or nitrogen) escapes from the water column, the water in the well will fall back to near static levels and give rise to a flow reversal from the well into the formation. This pulsed jetting should be repeated for the entire length of screened interval by lowering the jetting pipe in small increments. The pulsed jetting will loosen sediment from the screen, the filter pack, and the well bottom.

6.4.5.4 As material is loosened during the pulsed jetting, the well should be air-lift pumped to remove the dislodged sediment. Air-lift pumping is accomplished by slowly but steadily opening the line valve. This will discharge nitrogen into the water column within the well. The water will rise in the well as the nitrogen is introduced and expands. If the water level reaches the top of the well before the injected nitrogen reaches the top of the water column, "successful" air-lift pumping will occur. Air-lift pumping can continue as long as water is entering the well at a fast enough rate to maintain an aerated water column that extends to the top of the well.

6.4.5.5 Repeat the combination of pulsed jetting over the length of the well screen and air-lift pumping at least once. If the capacity of the well is not returned to near-original levels, or if the clarity of the well water fails to improve after the second cycle, the nitrogen-jetting redevelopment process shall be continued until the capacity of the well and the clarity of the water cease to improve.

#### 6.4.6 Surge-Blocking Redevelopment Procedure

6.4.6.1 Lower the surge block into the well to a position below the water level in the well but above the top of the screened interval, if possible. Surging action should be initiated very gently to loosen obstructing sediment. As the circulation improves during the redevelopment, more vigorous surging should be undertaken.

6.4.6.2 After operating the surge block over a given depth for several minutes, lower it to the next interval and repeat the surging action. This process should be repeated until surge blocking has been conducted over the entire screened interval.

6.4.6.3 After surge-blocking the entire screened interval, the surge block should be removed. Install

a suction-lift pump intake and a submersible pump or a foot-valve pump, and pump water from the well to remove the dislodged sediment. An effort should be made to pump accumulated sediment from the bottom of the well. Pumping should continue until the discharged water is clear and several bore volumes have been removed.

6.4.6.4 The process of surge blocking and then pumping should be repeated at least once. If the capacity of the well is not restored to near-original levels, or if the clarity of the well water fails to improve after only two surge-and-pump cycles, the complete process should be continued until the capacity of the well and the clarity of the water cease to improve.

#### 6.4.7 Suction-Lift Pumping

6.4.7.1 Suction-lift pumping is most suitable to use in combination with either surge-blocking or nitrogen-jetting. When used with either of these techniques, suction-lift pumping is an effective means of removing suspended sediment particles and accumulated sediment that have collected at the bottom of a well. When used alone, suction-lift pumping is also capable of providing only limited improvement in the capacity of a well.

6.4.7.2 When using suction-lift pumping in combination with surging or jetting, the suction-lift pump should be used to remove any accumulated sediment from the bottom of the well. This should be done prior to surging or jetting. Subsequently, the suction-lift pump should be used after each surging or jetting cycle to remove loosened sediment particles. Suction-lift pumping is conducted by simply installing the intake line in the well, connecting it to the pump intake port, and turning on the pump. Suction-lift pumping should then continue until the discharge water is clear. Suction-lift pumping can only be used if the depth to water is less than approximately 25 to 30 feet.

6.4.7.3 When using suction-lift pumping as the sole means of development, "over-pumping" is used to remove entrapped sediment from the well screen, filter pack, and formation. For this approach, the intake line is installed at the bottom of the well, and the well is pumped at its maximum rate for extended periods (in excess of 10 minutes) and then allowed to recover. The process is repeated until maximum improvements in capacity and/or well-water clarity have been achieved.

#### 6.4.8 Submersible Pumping

6.4.8.1 Submersible pumps may also be used in conjunction with surging or jetting for well development. Submersible pumps are not as effective as suction-lift pumps for pumping water with large amounts of suspended sediment (particularly sand-size sediment). Additionally, submersible pumps cannot be used to pump accumulated sediment from the bottom of a well. For this reason, submersible pumping should not be used as the sole means of developing a well, as can be done when using a suction-lift pump. The sequence of surging or jetting and submersible pumping should continue until the capacity of the well and the clarity of the water cease to increase.

6.4.8.2 When using a submersible pump in conjunction with surging or jetting, the pump should be installed after completion of each surging or jetting episode. To provide for maximum removal of suspended sediment, the submersible pump should be lowered to the bottom of the well on a suspension cable. For small pumps and shallow wells, the cable can be lowered by hand. For large pumps or deep wells, the weight of the pump and the discharge hose requires that a cable reel mounted on a tripod or vehicle be used for lowering and retrieving the pump.

6.4.8.3 After the pump is lowered into position, the electrical cord should be connected to a power supply. Do not connect the electrical cord to the power supply until the pump is installed in the well. Some submersible pumps are not grounded and could electrocute an individual if the pump is touched while turned on. After turning on the pump, continue pumping until the discharge water is clear.

6.4.8.4 After the discharge water becomes clear (or ceases to improve) and the pump is disconnected from the power supply, remove the pump by lifting or cranking up the suspension cable. The pump should never be removed by lifting or pulling on the electrical cord or the discharge hose.

#### 6.4.9 Foot-Valve Pumping

6.4.9.1 A foot-valve pump is simply a length of semirigid hose or pipe with a foot valve attached to one end. A foot-valve pump uses the momentum of water contained in the "discharge line" to lift water from the well as the discharge line is rapidly moved up and down. The foot valve on the bottom opens during the downstroke, allowing

water to enter the discharge line. During the upstroke, a spring in the valve, combined with the weight of the water, forces the valve closed. A foot-valve pump can be used in conjunction with surging or jetting to remove entrapped sediment particles from a well. Foot-valve pumping is very effective for removing sand-size particles. The method is also very effective in removing accumulated sediment from the bottom of a well prior to initiating surging or jetting activity.

6.4.9.2 When using a foot-valve pump in conjunction with surging or jetting, the sediment in the bottom of the well should be removed prior to initiating surging or jetting activities. Install the foot-valve pump so that the lower end of the unit (the valve end) is at the bottom of the well. Commence pumping by rapidly raising and lowering the discharge line. As the line fills with water, its weight will increase. For shallow wells, this operation of the pump can be accomplished manually. For deep wells, the weight of the discharge line will require a mechanical means of raising and lowering the unit. Such mechanical devices typically consist of a specially made jack handle or a commercially made apparatus.

6.4.9.3 Once the initial pumping effort begins to produce water, pumping should continue until the discharge water is clear.

6.4.9.4 Surging or jetting should then be conducted, followed by another episode of foot-valve pumping. This sequence of steps shall be repeated until the capacity of the well and the clarity of the water cease to increase.

### 7. Precision and Bias

7.1 This standard practice presents guidelines for maintaining high-quality monitoring-well installations. Therefore, statements regarding precision and bias are not applicable, except in the context of such statements that might be included in Standard Test Method for the Measurement of Water Levels in Groundwater Monitoring Wells [LQ-2(T)].

### 8. Quality Assurance

8.1 To maintain quality control standards, the Well Maintenance Checklist must be completed for each well that undergoes inspection and maintenance. The checklist must be signed by the person completing the checklist. The checklist should then

be reviewed for correctness and completeness by the assistant well-maintenance technician. Any discrepancies should be corrected by the two well-maintenance technicians, and the assistant should sign the form as having verified the information. The checklist should then be filed in the Project Well Maintenance File.

## 9. Keywords

9.1 Air-lift pumping, foot-valve pumping, monitoring well, nitrogen-jetting, submersible pumping, surge-blocking, well inspection, well-maintenance, and well redevelopment.

Section A-13  
LC-24(T)

## Technical Comments on ASTM D 1889-88a

# Standard Test Method for Turbidity of Water

### Summary of ASTM D 1889-88a

This test method describes the measurement of turbidity in water and wastewater discharges using two types of instrumentation.

### Additions Applicable to Operating Contractor and Its Subcontractors

This addendum addresses specific procedures, equipment, and documentation requirements when using the HACH model 2100P portable turbidimeter to measure turbidity of ground water.

The following sections shall be interpreted in conjunction with the current published version of this ASTM procedure. These sections shall be interpreted in numerical order, using the published version as the base document for reference.

## 1. Scope

1.2.1 Turbidities up to 1000 NTU can be accurately measured using the HACH model 2100P portable turbidimeter.

1.3.1 Turbidities greater than 1000 NTU may be measured using the HACH model 2100P portable turbidimeter by serial dilution to below 1000 NTUs.

## 2. Referenced Documents

2.3 HACH Company Manual, *Model 2100P Portable Turbidimeter Instruction Manual*, Loveland, CO, 1992.

## 3. Terminology

3.2.2 *Turbidimeter*—An instrument used to measure the turbidity of an aqueous sample.

## 4. Significance and Use

4.3 Turbidity measurements are used as indicators of the effectiveness of well-development activities. Turbidity measurements also are used to determine when purging of a monitoring well is complete and ground water sampling can commence.

## 8. Interferences

8.3.1 Periodically apply a thin layer of silicone oil to the sample cell to mask minor imperfections and scratches in the glass.

## 9. Apparatus

### 9.5 *Portable turbidimeter:*

9.5.1 HACH model 2100P portable turbidimeter.

9.5.2 Glass sample cells.

9.5.3 Silicone oil.

9.5.4 AEPA-I styrene/divinylbenzene polymer primary standard or Formazin primary calibration solution.

9.5.5 Gelex secondary turbidity standards.

9.5.6 Battery eliminator.

9.5.7 Logbook.

9.5.8 Kimwipes or equivalent lint-free tissue.

## 10. Reagents

10.3 Routine primary calibration of the HACH 2100P turbidimeter requires 0, 20, 100, and 800 NTU solutions.

## 11. Calibration

11.1 A primary calibration of the turbidimeter must be conducted before each sampling event.

11.2.1 Press the input/output (I/O) switch to turn the power on.

11.2.2 Fill a clean sample cell with the same dilution water used to prepare the standards, or the 0 NTU standard.

11.2.4 Close the lid and press the CAL key followed by the READ key. The turbidimeter will read the value of the dilution water or the 0 NTU standard and use this value to calculate a correction factor for the 20 NTU standard.

11.2.5.1 The display will automatically advance to the next standard and show "20 NTU." Remove the dilution water or 0 NTU solution sample from the cell compartment and replace it with a sample cell containing the 20 NTU standard (orientation marks should always be aligned). Press the READ key.

11.2.6.1 The display will automatically advance to the next standard and show "100 NTU." Remove the 20 NTU standard from the cell compartment and replace it with a sample cell containing the 100 NTU standard. Press the READ key.

11.2.6.2 The display again will advance to the next standard and show "800 NTU." Remove the 100 NTU standard from the cell compartment and replace it with a sample cell containing the 800 NTU standard. Press the READ key.

11.2.7.1 After the display reads "SO," press the CAL key to complete the calibration and store the calibration information within the electronics of the turbidimeter.

## 12. Procedure

12.1 *Operational check with Gelex secondary standards.* When using a HACH model 2100P portable turbidimeter, the following steps replace section 12.1 found in the ASTM procedure.

12.1.1 After every primary calibration, values must be assigned to the Gelex standards for use in operational checks.

12.1.2 Clean the outside of the Gelex cells and apply a thin coating of silicone oil.

12.1.3 Place each of the Gelex standards in the cell compartment with the orientation marks aligned and press the READ key. Record the displayed value in the project logbook and mark the value on the cell above the band.

12.1.4 Before taking measurements, the turbidimeter must be operationally checked by placing the Gelex standards in the cell compartment and pressing the READ key. The displayed value must be within 10 percent of the assigned Gelex value obtained during primary calibration. If the

value falls outside the 10 percent criteria, a new primary calibration must be performed.

12.2.2 Turbidities up to 1000 NTUs can be measured without dilution of the sample using the HACH model 2100P portable turbidimeter.

12.2.3.2 Apply a thin film of silicone oil to the sample cell and wipe with a Kimwipe.

12.2.3.3 Place the sample cell in the instrument cell compartment with the orientation marks aligned.

12.2.3.4 Select manual or automatic range by pressing the RANGE key.

12.2.3.5 If the sample causes the display to change constantly, press the SIGNAL AVERAGE key.

12.2.3.6 Press the READ key. The display will show the turbidity in NTU. Record the value as specified in the project planning documents.

## 14. Precision and Bias

14.6 Accuracy of  $\pm 2$  percent and a repeatability of  $\pm 1$  percent, or  $\pm 0.01$  NTU (whichever is greater) can be expected using the HACH model 2100P portable turbidimeter.

## 15. Quality Assurance

15.1 Documentation for quality-assurance purposes when making turbidity measurements includes the following information:

15.1.1 Date and time of the primary calibration.

15.1.2 Manufacturer, expiration date, and NTUs of the primary calibration standards.

15.1.3 Values assigned to the Gelex secondary standards after the primary calibration.

15.1.4 Measurements of the Gelex standards prior to making the turbidity measurement.

15.1.5 Date and time of the turbidity measurement.

15.1.6 Measured sample turbidity.

15.1.7 Instrument manufacturer, model, and serial number of the turbidimeter.

15.1.8 Name of person performing the measurement.



**16. Keywords**

16.1 Calibration, nephelometric, NTU, turbidity, and turbidimeter.

**17. Hazard Analysis**

17.1 This test method may use Formazin for the preparation of calibration standards. Avoid contact

with skin and eyes; use adequate eye protection and disposable gloves.

17.2 Site-specific controls are available in the planning documents for a particular project.

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## Standard Test Method for Turbidity of Water<sup>1</sup>

This standard is issued under the fixed designation D 1889; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense. Consult the DoD Index of Specifications and Standards for the specific year of issue that has been adopted by the Department of Defense.*

### 1. Scope\*

1.1 This test method covers the determination of turbidity in water and wastewater.

1.2 This test method is applicable to the measurement of turbidities in the range from 0.05 to 40 nephelometric turbidity units (NTU).

1.3 Higher turbidities may be measured using this test method by serial dilution to applicable range.

1.4 This test method was tested on municipal drinking water and final effluent discharges. It is the user's responsibility to ensure the validity of this test method for waters of untested matrices.

1.5 *This standard may involve hazardous materials, operations, and equipment. This standard does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use. For a specific caution statement, see Note 3.*

### 2. Referenced Documents

#### 2.1 ASTM Standards:

D 1129 Definitions of Terms Relating to Water<sup>2</sup>

D 1192 Specification for Equipment for Sampling Water and Steam<sup>2</sup>

D 1193 Specification for Reagent Water<sup>2</sup>

D 2777 Practice for Determination of Precision and Bias of Applicable Methods of Committee D-19 on Water<sup>2</sup>

D 3370 Practices for Sampling Water<sup>2</sup>

#### 2.2 EPA Standard:

EPA 600/4-79-202 Methods for Chemical Analysis of Water and Wastes<sup>3</sup>

### 3. Terminology

3.1 **Definitions**—The terms turbidity, and nephelometric turbidity are defined in Definitions D 1129. For definitions of other terms used in this test method, refer to Definitions D 1129.

#### 3.2 Description of Term Specific to This Standard:

3.2.1 **turbidity**—an expression of the optical properties of a sample that causes light rays to be scattered and absorbed rather than transmitted in straight lines through the sample. (Turbidity of water is caused by the presence of suspended and dissolved matter such as clay, silt, finely divided organic matter, plankton, other microscopic organisms, organic acids, and dyes.)

### 4. Significance and Use

4.1 Turbidity in water is caused by the presence of suspended and dissolved particles of gas, liquid or solids of organic or inorganic matter. Turbidity is undesirable in drinking water, plant effluent waters, water for food and beverage processing, and for a large number of other water-dependent manufacturing processes. Removal of suspended matter is accomplished by coagulation, settling, and filtration. Measurement of turbidity provides a rapid means of process control for when, how, and to what extent the water must be treated to meet specifications. Methodology for the correlation of a sample NTU to the number or volume of suspended particles is now under evaluation. Specific gravity estimates would then give rapid NTU correlation to the weight concentration of suspended matter.

4.2 This test method is suitable to low and medium turbidity such as that found in drinking water and process water.

### 5. Summary of Test Method

#### 5.1 Nephelometric Turbidity:

5.1.1 **Photoelectric Nephelometer**—The photoelectric nephelometer operation is based on instrumental comparison of the intensity of light scattered by the contained static water sample under defined conditions to the intensity of light scattered by a reference standard in the sample container. The higher the intensity of scattered light, the higher the turbidity of sample.

5.1.2 **Calibrated Slit Turbidimeter**—The calibrated slit turbidimeter operation is based on a visual comparison of the intensity of light scattered by the contained static water sample under defined conditions to the intensity of light scattered by a reference sample in the same container, the higher the intensity of scattered light the higher the turbidity of sample.

#### 5.1.3 Nephelometric Turbidity Standards:

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D-19 on Water and are the direct responsibility of Subcommittee D19.07 on Sediments.

Current edition approved June 24, 1988. Published September 1988. Originally published as D 1889 - 61. Last previous edition D 1889 - 88.

<sup>2</sup> Annual Book of ASTM Standards, Vol 11.01.

<sup>3</sup> Available from Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, OH 45268.

5.1.3.1 AEPA-I styrene/divinylbenzene polymer standard (see Section 2). These standards are used as received from the distributor.<sup>4</sup>

5.1.3.2 Formazin polymer preparation and dilution methods are given in 10.2.2 to 10.2.4.

## 6. Purity of Reagents

6.1 Reagent grade chemicals shall be used in all tests. Unless otherwise indicated, it is intended that all reagents shall conform to the specifications of the Committee on Analytical Reagents of the American Chemical Society, where such specifications are available.<sup>5</sup> Other grades may be used providing it is first ascertained that the reagent is of sufficiently high purity to permit its use without lessening the accuracy of the determination.

6.2 Unless otherwise indicated references to water shall be understood to mean reagent water conforming to reagent water Type III Specification D 1193.

6.2.1 Standard dilution waters of Type III shall be prepared by filtration through a 0.2 to 0.22  $\mu\text{m}$  membrane or other suitable filter within 1 h of use to reduce background turbidity to less than 0.05 NTU.

## 7. Sampling and Sample Preservation

7.1 *Collection of Sample*—Collect the sample in accordance with the applicable standard, Specification D 1192 and Practices D 3370 or EPA 600/4-79-202 for EPA compliance.

7.2 *Storage of Sample*—Determine the turbidity on the day the sample is taken. If this is not feasible, store the sample in the dark for up to 24 h and refrigerate at 4°C if possible, but do not freeze. Prolonged storage is not recommended because of irreversible changes.

7.3 *Preparation of Sample*—Bring the sample to room temperature and shake sample vigorously for at least 1 min. Let the sample stand 2 to 3 min to allow air bubbles to disappear, then gently invert the sample several times or swirl mix before examination.

## 8. Interferences

8.1 Floating or suspended large particles and entrained air bubbles will give false or unstable readings. Certain turbulent motions also create unstable reading conditions of nephelometers.

8.2 Dissolved material that imparts a color to the water may cause serious errors in nephelometric reading unless the instrument has special compensating features.

8.3 Scratches, finger marks, or dirt on the walls of the sample cell may give erroneous readings. Cells should be kept scrupulously clean both inside and outside and discarded when they become etched or scratched. The cells must not be handled where the light strikes them when indexed in the instrument well.

NOTE 1—The same indexed cell should be used first for standardization followed by unknown determination.

NOTE 2—Indexing of the sample cell or tube to the instrument well is accomplished by placing a mark on the top of the glass cell and a similar mark on the upper surface of the well so that the cell can be placed in the well in an exact position each time.

## 9. Apparatus

9.1 Two types of instruments are available for the nephelometric method, the photoelectric nephelometer and the calibrated slit turbidimeter (Figs. 1 and 2). Both give a greater precision and sensitivity than the Jackson candle turbidity, within their applicable range from 0.05 to 40.0 NTU, to ranges as low as 0.05 to 1.00 NTU.

9.2 The sensitivity of the instruments should permit detection of differences of 0.02 NTU or less in waters having turbidities of less than 1.00 NTU. The instrument should measure the ranges from 0.05 to 1.00 NTU and 0.05 to 40.0 NTU with the additional ranges from 0.05 to 0.10 and 0.05 to 10.0 NTU if possible. Linear calibration charts should be made for each range used. Either of the two accepted standards, AEPA-I or Formazin, (10.2.1 or 10.2.2) can be used for this calibration. See 11.1 for calibration instruments.

### 9.3 Photoelectric Nephelometer:

9.3.1 This instrument uses a light source for illuminating the sample and one or more photoelectric detectors with a readout device to indicate the intensity of light scattered at right angles (90°) to the path of the incident light. The photoelectric nephelometer should be so designed that little stray light reaches the detector(s) in the absence of turbidity and should be free from significant drift after a short warm-up period.

9.3.2 Differences in physical design of photoelectric nephelometers will cause differences in measured values for turbidity, as will aging of a turbidimeter, even though the same suspension is used for calibrations. To minimize initial differences, the following design criteria should be observed (see Fig. 1).

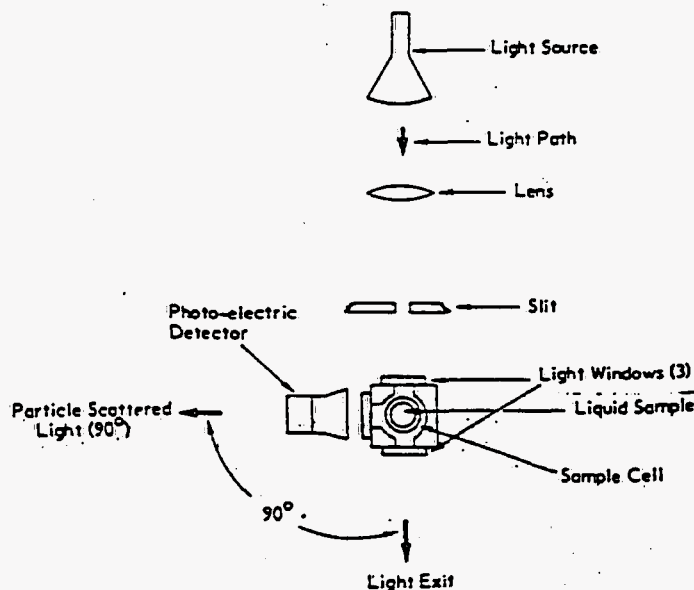


FIG. 1 Photoelectric Nephelometer

<sup>4</sup> Patents 4,283,143 and 4,291,980, available from, Advanced Polymer Systems, Inc., 3696 Haven Ave., Redwood City, CA 94063, have been found satisfactory for this purpose.

<sup>5</sup> "Reagent Chemicals, American Chemical Society Specifications," Am. Chemical Soc., Washington, DC. For suggestions on the testing of reagents not listed by the American Chemical Society, see "Reagent Chemicals and Standards," by Joseph Rosin, D. Van Nostrand Co., Inc., New York, NY, and the "United States Pharmacopoeia."

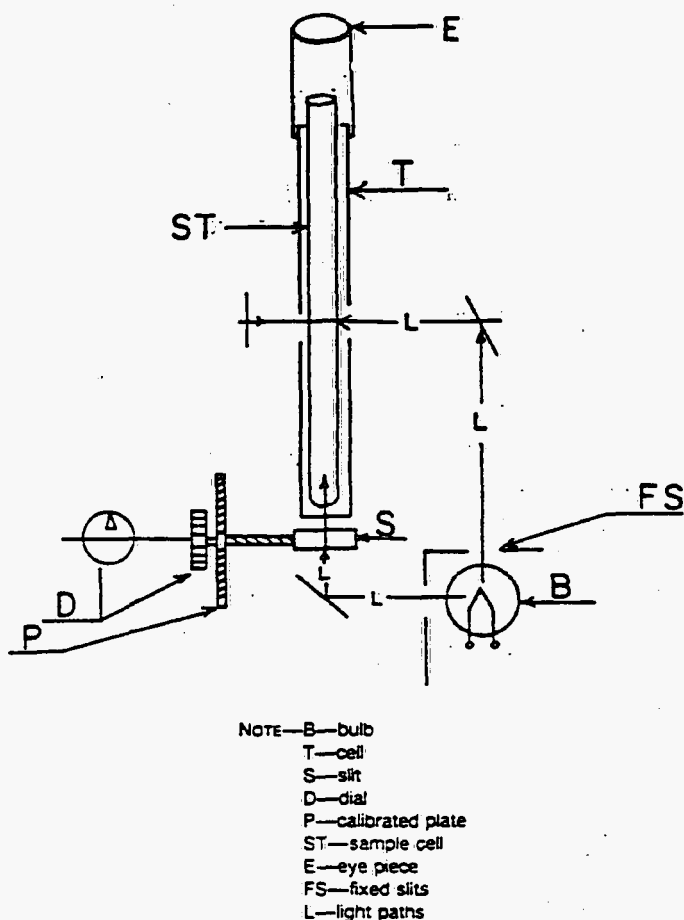


FIG. 2 Calibrated Slit Turbidimeter

9.3.2.1 *Light Source*—Tungsten lamp operated at a color temperature between 2200 and 3000 K.

9.3.2.2 Distance traversed by incident light and scattered light within the sample, total not to exceed 10 cm.

9.3.2.3 *Angle of Light Acceptance to the Detector*—Centered at 90° to the incident light path and not to exceed  $\pm 30^\circ$  from the 90° scatter path center line.

9.3.3 The sample tube used in calibration and sample measurement must be the following:

9.3.3.1 Clear, colorless glass, be kept scrupulously clean, both inside and out, and discarded when it becomes etched or scratched.

9.3.3.2 Index marked so that repeated exact placements into the instrument cuvette well for measurement can be made.

9.3.3.3 Handled where the light path does not pass during measurement. Provision should be made in design to give the tube a proper place in which to handle the tube during calibration or sample measurement procedure. Instrument and sample tube design criteria are given in EPA 600/4-79-202.

#### 9.4 Calibrated Slit Turbidimeter:

9.4.1 This instrument uses principles based on the Tyndall effect. A beam of light passing up through the sample is compared to the light scattered upward by suspended particles in the turbid solution which has been

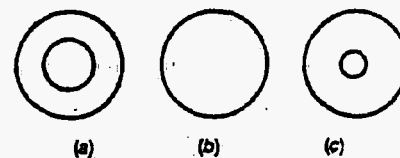


FIG. 3 Eye Piece Fields (Calibrated Slit)

illuminated from the side at 90°.

9.4.2 As shown in Fig. 2, light from the bulb, B, is reflected to illuminate the turbid solution in the cell; T, from the side. Light scattered upward by the suspended particles in the solution is seen through an eye piece as the outer portion of a circular split field (as in Fig. 3). Light also passes through a dial operated adjustable slit, S, and is reflected upward through the sample. In the eye piece this light is seen as the center circular field. Depending on the amount of light permitted through the adjustable slit, the center field will appear higher or darker than the outer portion, as shown in Fig. 3(a) and 3(c). The operator turns the dial controlling the slit until the entire field is of uniform brightness as shown in Fig. 3(b). Dial calibration charts should be based on at least five concentration levels, (across the 0.05 to 40 NTU range) of prepared AEPA-I or in-house fresh preparations and dilutions of Formazin. 40 NTU has been selected by EPA as the maximum concentration or turbidity that is the upper limit of linearity for measuring instruments even though there are some instruments that are linear above 40 NTU.

NOTE 3: Caution—Care should be exercised if Formazin standardization is used as Formazin has a rapid settling rate, so sample should be remixed at least every 15 min.

9.4.2.1 From this prepared chart slit dial reading can be translated into NTU values. Prior to unknown water sample determination, a single standard point determination should be made to check cell cleanliness and other instrument optics, such as lamp operation.

9.4.2.2 Because the eye is used to detect the null-point, the observer can compensate and disregard the presence of sample color and extraneous debris.

## 10. Reagents

10.1 Dilution and final rinsing water, see 6.2.

### 10.2 Turbidity Standards:

10.2.1 AEPA-I turbidity standards are prepared sealed stable suspensions of styrene divinylbenzene which are opened and used as received from manufacturer. Note that all standard Formazin diluted concentrations of AEPA-I are available from the manufacturer.

NOTE 4—Sealed or solid samples will not standardize nephelometers for the turbidity measurement of water or waste. These two methods (sealed or solid examples) neglect the zeroing out of sample tube (cuvette) prior to making water measurement in the tube.

10.2.2 *Formazin Turbidity Suspension, Stock (400 NTU)*—A stock turbidity suspension for Formazin polymer is prepared by reacting hydrazine sulfate with hexamethylenetetramine under carefully controlled conditions. (See EPA 600/4-79-202.)

10.2.2.1 *Solution I*—Dissolve 1.00 of hydrazine sulfate  $[(\text{NH}_2)_2\text{H}_2\text{SO}_4]$  in dilution water and dilute to mark in a 100-mL volumetric flask.

10.2.2.2 *Solution II*—Dissolve 10.0 of hexamethylenetetramine (practical grade, ACS grade not available) in dilution water and dilute to mark in a 100-mL volumetric flask.

10.2.2.3 Into a third 100-mL volumetric flask, pipet 5.00 mL of Solution I and with a clean pipet add 5.00 mL of Solution II. Mix the two solutions and allow to stand for 24 h at  $25 \pm 3^\circ\text{C}$ . After reaction, dilute to mark with water and mix. The freshly mixed turbidity of this solution is 400 NTU. This 400 NTU stock has to be prepared monthly.

10.2.3 *Formazin Turbidity Suspension, Standard (40 NTU)*—Pipet 10.0 mL of mixed 400 NTU stock into a 100-mL volumetric flask and dilute with water to mark. The turbidity of this suspension is defined as 40 NTU. This 40 NTU suspension has to be prepared weekly.

10.2.4 *Dilute Formazin Turbidity Suspension Standard*—Prepare dilute turbidity suspension below 4.0 NTU daily. Those above 4.0 NTU have a useful life of one week. Prepare each dilution by pipetting the volume of 40 NTU into a 100-mL volumetric flask and diluting to mark with water; so that 50.0 mL of 40 NTU diluted to 100 mL is 20.0 NTU and 10.0 mL of 40 NTU diluted to 100 mL is 4.00 NTU.

10.2.4.1 To prepare dilute suspensions having turbidities of less than 1.0 NTU use an appropriate volume of 4.0 NTU suspension in a 100-mL volumetric flask and dilute to mark. Prepare dilutions below 4.0 NTU daily.

## 11. Calibration

11.1 Follow the manufacturer's operating instructions.

Calibrate the instrument range of interest with standards (see AEPA-I and Formazin standards). If the instrument control dial, meter, or output digital reading is already in NTUs, this procedure and curve will check the accuracy of the instrument output. Use at least three standard concentrations (NTU) to calibrate each instrument range. Photoelectric nephelometers have a calibration adjustment. Set this adjustment to equal the high value of standard for the range of interest. Read the standards used for the calibration of the range in the same tube as was the high level adjustment. Note and graph the instrument value for each standard (instrument reading versus standard value). See Fig. 4 as an example. For daily use of the instrument, one standard in the use range will be all that is required to set the calibration adjustment at the graph reading for that value. The aging drift characteristics of each instrument will determine the recalibration requirement.

11.1.1 Clean the cell after filling with turbidity standard or test water samples as follows:

11.1.1.1 Rinse the clean dry cell twice with the suspension with which it is to be filled.

11.1.1.2 Fill the cell to a level to where the top air-liquid interface will not interfere with the subsequent reading. Check manufacturer recommendations as to cell filling.

11.1.1.3 After the cell is filled, tissue is then used to remove all traces of dirt or fingerprints. Tissue alone does not clean very dirty cells and one of the common nonabrasive glass cleaners may be necessary.

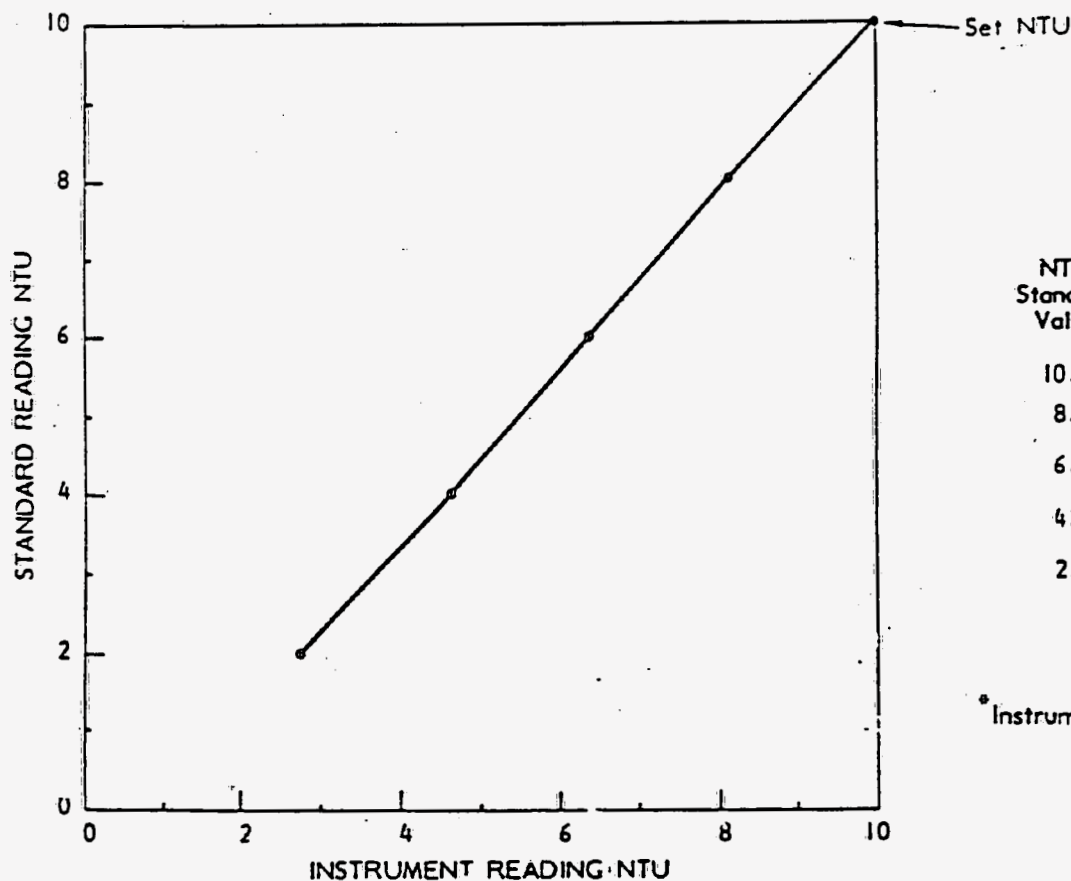


FIG. 4 Linear Calibration LC-10

Table

| NTU<br>Standard<br>Value | NTU<br>Instrument<br>Reading |
|--------------------------|------------------------------|
| 10.0                     | 10.0*                        |
| 8.0                      | 8.1                          |
| 6.0                      | 6.3                          |
| 4.0                      | 4.7                          |
| 2.0                      | 2.8                          |

\* Instrument adjusted to read this value



11.1.1.4 The cleaned cell is handled by its very top and placed in an indexed manner in the instrument.

#### 11.2 Calibration Steps:

11.2.1 Warm up the instrument according to manufacturer's instructions.

11.2.2 Rinse a clean, dry, scratch-free index marked cell with the highest concentration of the standard for the instrument range setting or range of interest, and then fill. Always clean the exterior of the cell after filling in any of the following procedures.

11.2.3 Place the cell in the instrument in an oriented manner ready for reading of turbidity.

11.2.4 For photoelectric nephelometrics, set the calibration adjustment for the labeled value of AEPA-I turbidity standard or the diluted value of Formazin standard. For slit type nephelometers plot the adjusted dial reading at null or uniform field brightness versus NTU value of turbidity standard.

11.2.5 Remove the sample cell and discard the first turbidity standard. Rinse and fill a second value of turbidity standard and place the cell in the instrument in an oriented manner. Without moving the photo-electric calibration adjustment, make a reading. Plot this instrument NTU reading against the NTU value of the turbidity standard. For the slit type nephelometer again plot the adjusted dial reading at null versus NTU value of the turbidity standard.

11.2.6 Repeat for at least one more turbidity standard NTU value which should cover the turbidity range of interest. The greater the number of turbidity standard values used, the greater the reliability of the calibration.

11.2.7 Make the plot of instrument reading or dial setting versus turbidity standard NTU value to where any instrument reading or dial setting within the range calibrated is corrected to values relative to the turbidity standard values. The plot of instrument reading or dial setting versus turbidity standard value is a range calibration curve. Calibration curves for each usable range should be made. See Fig. 4 for an example of a linear calibration curve.

### 12. Procedure

12.1 Standardize the instrument with one value (NTU) of turbidity standard in the measurement range of interest.

12.1.1 Warm up the instrument according to the manufacturer's instructions.

12.1.2 Rinse a clean, dry, scratch-free index marked (a felt pen dot) cell with a turbidity standard (AEPA-I or Formazin) with a value (NTU) in the range of interest. Fill the cell with this turbidity standard. Clean the cell's exterior.

12.1.3 Place the filled clean cell in an indexed manner in the instrument and read the value. It will be an NTU reading for photoelectric types and a dial reading for slit types nephelometers.

12.1.4 From the calibration curve for this instrument's range, determine the required reading for the turbidity standard in cell.

12.1.4.1 Move calibration adjustment to give the photoelectric nephelometer the required NTU reading.

12.1.4.2 The slit dial reading determined from the calibration curve for the turbidity standard in the cell should be within 5 % of the dial reading. If not, reclean the cell and recalibrate.

#### 12.2 Measurement of Water Turbidity:

12.2.1 *Turbidity Less Than 40 NTU*—Shake the sample to thoroughly disperse the solids. Allow air bubbles to disappear, then proceed.

12.2.2 *Turbidity Exceeding 40 NTU*—Dilute the sample with one or more equal volumes of reagent water until turbidity is below 40 NTU after mixing and degassing. Then treat this less than 40 NTU turbidity in accordance with 12.2.1. The turbidity of the original sample can then be computed based on dilution data and original sample volume (variations of particle size can affect dilution).

12.2.3 After calibration check or adjustment, empty the cell (do not change cells for measurement) of turbidity standard and rinse the empty cell with the water sample to be tested.

12.2.3.1 The measured NTU value of the water sample is determined using the instrument value and the appropriate calibration curve.

### 13. Report

13.1 Report results as follows:

| NTU       | Report to Nearest (NTU) |
|-----------|-------------------------|
| 0.05-1.00 | 0.05                    |
| 1.00-10.0 | 0.1                     |
| 10.0-40   | 1.0                     |
| 40-100    | 5.0                     |
| 100-400   | 10                      |
| 400-1000  | 50                      |
| >1000     | 100                     |

### 14. Precision and Bias<sup>6</sup>

14.1 Round-robin data for this test method were obtained by the use of AEPA-I standards. EMSL (Environmental Monitoring and Support Laboratory, EPA, Cincinnati, Ohio) examined this data for its statistical significance. For other matrices, these data may not apply.

14.2 Formazine was not used in the round-robin test because of its short term stability. Formazine can be used as a fresh short-term calibration mixture but the results might not be applicable to this collaborative test study.

14.3 Polymer suspensions of styrene divinyl-benzene are stable and can be accurately quantitated by gravimetric procedures. Linear calibration of each instrument was performed prior to collaborative study, involving ten laboratories and three nephelometric turbidity unit (NTU) levels.

14.4 Table 1 shows the required statistical treatment of the turbidity round-robin test for nine laboratories and three concentrations of NTUs and one laboratory's results were statistically rejected.

14.5 Table 2 shows that the bias of all NTU levels is insignificant for the round-robin test.

<sup>6</sup> Supporting data are available from ASTM Headquarters. Request RR: D19-1129.

TABLE 1 Final Statistics<sup>A</sup>

|                                           |       |        |       |
|-------------------------------------------|-------|--------|-------|
| True concentration, C                     | 0.92  | 4.50   | 18.66 |
| Mean response, $\bar{x}$                  | 0.972 | 4.410  | 18.57 |
| Bias, $\bar{x} - C$                       | 0.052 | -0.090 | -0.09 |
| Total standard deviation, $S_T$           | 0.091 | 0.361  | 0.292 |
| Single-operator standard deviation, $S_o$ | 0.044 | 0.174  | 0.181 |

<sup>A</sup> Represent three concentrations of NTU.

TABLE 2 Bias Results

|                                                           |       |        |       |
|-----------------------------------------------------------|-------|--------|-------|
| True concentration, C                                     | 0.92  | 4.50   | 18.66 |
| Mean response, $\bar{x}$                                  | 0.972 | 4.410  | 18.57 |
| Bias = $\bar{x} - C$                                      | 0.052 | -0.090 | -0.09 |
| Total standard deviation, $S_T$                           | 0.091 | 0.361  | 0.292 |
| Number of lab/operators contributing usable data, n       | 8     | 8      | 8     |
| Student's t-value, $t =  \text{bias}  / (S_T / \sqrt{n})$ | 1.62  | 0.71   | 0.87  |
| Critical t-value from Table X3.8 of Practice D 2777       | 2.365 | 2.365  | 2.365 |
| Is bias significant, is $t > \text{critical } t$ ?        | no    | no     | no    |

## SUMMARY OF CHANGES

This section identifies the location of selected changes to these test methods that have been incorporated since the last issue. For the convenience of the user, Committee D-19 has highlighted those changes that may impact the use of these

test methods. This section may also include descriptions of the changes or reasons for the changes, or both.

(1) Former Test Method B (Visual Jackson Candle Turbidity) was deleted.

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*This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.*





Technical Comments on ASTM D 4409-95

# Standard Test Method for Velocity of Water in Open Channels with Rotating Element Current Meters

## Summary of ASTM D 4409-95

This ASTM method describes the design and use of specific types of rotating-element current meters to measure water velocities in open channels.

## Additions Applicable to GJO Contractors and Their Subcontractors

The following sections shall be interpreted in conjunction with the current published version of the ASTM method. The sections shall be interpreted in numerical order, using the published version as the base document for reference.

### 6. Interferences

6.3 Selection of a representative section of the stream channel to make measurements can minimize the effects of natural variation on measurement accuracy. The following factors should be considered when selecting a section of stream to measure velocity.

6.3.1 Straight stream reaches are preferred.

6.3.2 Uniform flow within a single, well-defined, smooth channel is preferred with no overbank or underbank flow.

6.3.3 Avoid overhanging brush and submerged vegetation.

6.3.4 Avoid irregular, rough stream bottoms.

6.3.5 Avoid eddied, turbulent, and stagnant water.

### 10. Field Use and Maintenance

10.7 Observe rotating elements (if visible) during velocity measurement to confirm proper operation.

### 13. Quality Assurance

13.1 A duplicate velocity measurement should be collected and recorded every 20 measurements as a check on measurement precision.

13.2 The following information should be documented when making velocity measurements.

13.2.1 Manufacturer, model, and serial number of the current meter.

13.2.2 Calibration information and date of calibration.

13.2.3 Count time of velocity measurements.

13.2.4 Date, time, units, location, and magnitude of the velocity measurements.

### 14. Hazard Analysis

14.1 This method may involve personnel in or around potentially dangerous waterways that have an associated drowning hazard. If the task of measuring the discharge of a waterway is identified as a project requirement during the planning phase, then a hazard analysis will be conducted, and the appropriate precautions and safety equipment will be specified in the project health and safety plan. If the discharge measurement task was not anticipated at the start of the project, then a Job Safety Analysis will be conducted, and, if required, the appropriate precautions and required safety equipment will be specified in a Safe Work Permit.

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# Standard Test Method for Velocity Measurements of Water in Open Channels with Rotating Element Current Meters<sup>1</sup>

This standard is issued under the fixed designation D 4409; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method describes the design and use of cup-type or vane-type vertical axis current meters and propeller-type horizontal axis current meters for measuring water velocities in open channels.

1.2 This test method is intended primarily for those meters customarily used in open-channel hydraulic (as distinguished from oceanographic) applications with an operator in attendance.

1.3 This test method is intended primarily for current meters that measure one component or filament of flow.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

D 1129 Terminology Relating to Water<sup>2</sup>

D 2777 Practice for Determination of Precision and Bias of Applicable Methods of Committee D-19 on Water<sup>2</sup>

D 3858 Test Method for Open-Channel Flow Measurement of Water by Velocity-Area Method<sup>2</sup>

### 2.2 ISO Standards:

ISO 2537 Liquid Flow Measurement in Open Channels—Rotating Element Current Meters<sup>3</sup>

ISO 3454 Liquid Flow Measurement in Open Channels—Direct Depth Sounding and Suspension Equipment<sup>3</sup>

ISO 3455 Liquid Flow Measurement in Open Channels—Calibration of Rotating-Element Current Meters in Straight Open Tanks<sup>3</sup>

## 3. Terminology

3.1 **Definitions**—For definitions of other terms used in this test method, refer to Terminology D 1129.

### 3.2 Descriptions of Terms Specific to This Standard:

3.2.1 **current meter**—an instrument used to measure the speed or velocity of flowing water at a point.

3.2.2 **Price-type current meters**—generic name for specific

vertical axis meters with a rotating element consisting of six conical cups and constructed as described in Refs (1–3).<sup>4</sup>

3.2.3 **spin test**—a test performed to check the bearings of a current meter. This test is used primarily with vertical axis current meters.

3.2.4 **turbulence**—irregular condition of flow in which the velocity exhibits a random variation with time and space coordinates so that statistically distinct average values can be discerned.

## 4. Summary of Test Method

4.1 The angular velocity of the rotating element is a function of water speed at the point of immersion. This angular velocity is determined from the meter output and its functional relation to the water speed is determined by calibration.

## 5. Significance and Use

5.1 This test method describes the design and use of various types of current meters. These current meters are commonly used to measure the velocity at a point in an open channel cross section as part of a velocity-area traverse to determine the flowrate of water. To this end it should be used in conjunction with Test Method D 3858.

## 6. Interferences

6.1 As with any intrusive flow measuring device, rotating element current meters are subject to damage by debris, especially in high velocity flows, and to fouling by floating materials such as aquatic growths and sewage.

6.2 Owing to bearing friction, each rotating element current meter has a limiting low velocity below which it does not function reliably. This velocity is different for each type of meter but, in general, % errors tend to become large as the velocities decrease below 0.1 to 0.2 ft/s (0.03 to 0.06 m/s).

## 7. Apparatus

7.1 **Current Meters**—Rotating element current meters consist of a rotating element with shaft and bearings, a mechanism for detecting and registering revolutions, and a frame which supports the foregoing elements and provides for suspension of the meter and the insertion of stabilizing fins if needed. Current meters covered by this test method do not customarily incorporate direction-measuring devices (see 11.1.5).

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D-19 on Water and is the direct responsibility of Subcommittee D19.07 on Sediments, Geomorphology, and Open-Channel Flow.

Current edition approved Dec. 10, 1995. Published February 1996. Originally published as D 4409 - 84. Last previous edition D 4409 - 91.

<sup>2</sup> Annual Book of ASTM Standards, Vol 11.01.

<sup>3</sup> Published by International Standards Organization and available from American National Standards Institute, 11 W. 42nd St., 13th floor, New York, NY 10036.

<sup>4</sup> The boldface numbers refer to the list of references at the end of this test method.

**7.1.1 Rotor Configuration**—Horizontal-axis meters have propeller-type rotors comprised of two or more blades. Interchangeable elements of different pitch or diameter can be used to cover a wider range of velocities. Vertical-axis meters have a rotating wheel made up of several cup-type or vane-type elements. Rotors employing six conical cups (for example, Price-type meters) are frequently used but other configurations are permissible provided the following requirements are met:

7.1.1.1 The relation between velocity and rotation rate must be stable, that is, there should be no significant uncertainties in the meter's rating curve due to unstable flow separations at the cups or similar hydrodynamic causes.

7.1.1.2 If fractions of revolutions are to be registered, the angular movement of the rotor must be the same during each measured fraction.

**7.1.2 Bearings:**

7.1.2.1 Bearing design shall permit the meter to be used in sediment-laden water, without affecting the accuracy of the meter.

7.1.2.2 If a particular oil is required for bearing lubrication, the supplier shall furnish it with the instrument. Information for obtaining replacement oil shall also be furnished.

7.1.2.3 At the highest velocity claimed for the meter, properly maintained bearings shall function without adversely affecting meter performance for a period of time customarily associated with normal use or for the period of time between recommended recalibrations. If bearing replacement is needed to meet this requirement, such replacement shall be possible in the field.

7.1.2.4 At the lowest velocity claimed for the meter, properly maintained bearings shall function consistently and not contribute to undue deviations in meter response.

7.1.2.5 No breaking-in period for the bearings shall be required after meter delivery.

**7.1.3 Registering Revolutions**—The current meter shall be equipped with a mechanism which detects and signals either single revolutions of the rotor or known fractions or multiples thereof. This detection can be by mechanical-electric contact, by magnetic, optical, or other methods, and shall produce a signal which is audible, visible, or recordable by other means.

7.1.3.1 A mechanical-electric contact device shall not add in any significant manner to the internal friction at the lowest velocity claimed for the meter.

7.1.3.2 The contact device must always actuate the signal at precisely the same position in each revolution (fraction or multiple).

7.1.3.3 If the revolution count is to be made manually by the operator, the audible or visual signals (as distinguished from recorded signals) shall not occur at a frequency greater than 3, and preferably 2.75, cps.

7.1.3.4 A timing device is a necessary adjunct to the meter so that the revolution rate can be determined from the revolution count. In the simplest configuration this system can consist of a manual stopwatch for timing audible or visual signals.

7.1.3.5 If the current meter system has a direct readout in velocity units, the user must be furnished an accuracy statement which includes the readout. Also, the user must be

provided with a procedure to check for system malfunctions.

**7.1.4 Frame**—The frame houses the current-meter elements and provides for suspending the meter in the flow. Depending upon the intended use of the meter, the frame can be designed for suspension by rigid rod only, by cable-and-weight only, or it can provide for both types of suspension.

7.1.4.1 The connection for rod mounting shall provide, in conjunction with the rod, rigidity and vibration-free performance at the highest velocity claimed for the meter, and shall provide for adjustable meter position along the rod. Fixed rod position is necessary for some applications, such as for measuring through ice cover. Rods must be provided with suitable fixtures to accommodate fins as specified in 7.1.4.3.

7.1.4.2 The connection for cable suspension shall permit the meter to swivel in a vertical plane so that it can seek and maintain a horizontal orientation.

7.1.4.3 **Fins**—Meters to be suspended by cable must provide for stabilizing fins to be inserted into the frame. Provision shall be made for balancing the meter-fin unit about its pivot while immersed in water, so that it can operate in a level position at all velocities claimed for the meter.

**7.1.5 Other General Requirements:**

7.1.5.1 The meter design and construction shall be sufficiently sturdy for normal field use and the materials shall be usable in normally encountered fresh and saline waters without undue corrosion or wear.

7.1.5.2 The meter shall offer low resistance to the flow and must be able to maintain a stable position with respect to the flow.

7.1.5.3 Meter parts shall be interchangeable among other meters of the same model and manufacturer. The manufacturer shall state which parts can be replaced without requiring recalibration.

7.1.5.4 Design features which permit minor repairs or parts replacement by the user in the field are encouraged. Any special purpose tools needed for such repairs or replacement shall be furnished with the meter.

7.1.5.5 For high-inertia, vertical-axis meters, spin test durations shall be recommended for effective use of the meters at their lowest claimed velocity. See Refs (1-3) for Price-type meters. Users shall be provided with alternative procedures for qualitative indications of internal friction in meters that are not amenable to spin testing.

7.1.5.6 The user shall be provided with the means (detailed dimensions, templates, or forms) to ascertain gradual changes in rotor configuration, where appropriate. See also 10.2.

7.1.5.7 Information on depth (pressure) limitation on meter submergence and on temperature effects, if any, on meter performance shall be furnished by the manufacturer.

**7.2 Suspension Equipment**—Description and requirements for suspension equipment are available in Refs (2, 3) and ISO 3454. This test method includes only those elements which directly affect the meter performance.

7.2.1 **Rods**—The rod for which the meter rating is valid, if not furnished with the meter, shall be precisely specified with regard to dimensions and configuration.

**7.2.2 Cable and Weight:**

7.2.2.1 The cable suspension system for which the meter

rating is valid, if not furnished with the meter, shall be precisely specified with regard to dimensions and configuration, including dimensions of the sounding weight, its distance from the meter, connecting strap details, cable dimensions, etc.

7.2.2.2 The weight shall offer minimal resistance to the flow and should be able to maintain a stable and level position. It shall be so shaped that the current meter is not subject to shed eddies or other instabilities; and it shall be heavy enough to avoid excessive downstream deflection of the cable, particularly in deep and swift currents. If some deflection is unavoidable, tables for air-line and wet-line corrections are available.

7.2.2.3 The suspension cable preferably shall be reverse-lay sounding cable to minimize torque on the immersed meter and weight. However, even this type of cable may cause or allow meter yaw and subsequent meter registration errors for Price-type current meters in velocities below 1.00 ft/s (0.305 m/s).

7.2.2.4 For protection of the meter it is preferable that the weight be mounted below the meter.

## 8. Sampling

8.1 Sampling, as defined in Terminology D 1129, is not applicable in this test method. Sampling to obtain a reliable measurement of average velocity in a cross section is covered in Test Method D 3858.

## 9. Calibration

### 9.1 General Calibration Requirements:

9.1.1 The range of calibration velocities ideally includes the minimum and maximum velocities claimed for the meter. Practically, most calibration (rating) facilities cannot achieve this range of velocities and are limited to 0.10 ft/s (0.03 m/s) to 12 ft/s (3.66 m/s). Calibrations at those minimum and maximum possible velocities, along with enough intervening points, typically describe a rotation rate-velocity relation that brackets values commonly found in flowing streams. For the rare cases where current meters are used to measure faster velocities, linear upward extension can be made with minimal accuracy degradation. Downward extrapolation may result in larger errors, due to variable stall rates of individual meters. Provide the rating to the user in the form of an equation, table, or graph. Furnish an estimate of the accuracy.

9.1.2 Make individual calibrations, using the same suspension with which the meter is to be used in the field. See 7.2.1 and 7.2.2.1.

9.1.3 If a propeller meter is intended to respond only to the velocity component along the meter axis, provide calibration information on this capability for the usable range of approach angles claimed for the meter.

9.1.4 Recalibrate meters when their performance is suspect. Some organizations establish routine recalibration policies, such as annually or based on hours of use. In the case of instruments made to stringent specifications, repairs and parts replacement may be made without recalibration requirements.

9.2 *Towing Tank Calibration*—Current meters usually are calibrated (rated) in a towing tank. Guidelines for this type of calibration are given in ISO 3455.

9.3 *Water Tunnel Calibration*—Current meters also can be calibrated in flowing water—in a facility that provides a uniform velocity distribution in a test area large enough to avoid blockage effects, provided that the accuracy of the system is demonstrably high. If this procedure is used, provide some indication of the scale and intensity of the turbulence.

9.4 *Group Ratings*—A rating equation provided by a manufacturer for a specific type of current meter is sometimes used in place of an individual calibration equation.

9.4.1 Base group ratings can be made, based on individual ratings of a significant number of meters with specified type of suspension (4). Preferably both new and well-maintained used meters should be included. Make the size, make-up, and standard deviation of the sample known to the user.

9.4.2 A group rating pertains only to current meters manufactured in a specific manner. Any change in the manufacturing process requires reexamination of the group equation and appropriate adjustment if needed.

## 10. Field Use and Maintenance

### 10.1 Spin Tests (see also 7.1.5.5):

10.1.1 Make spin tests for meters that are amenable to spin tests at least once during each day's use. More frequent testing is recommended when velocities are low, when silt concentration is high, or a meter malfunction is suspected.

10.1.1.1 Spin tests must be made with the meter supported in a level and wind-free environment. The spin shall meet the specified duration after a firm manual start and shall come to a gradual stop. Spin duration information must be supplied by the manufacturer for a specific meter. Some organizations provide spin duration requirements for meter types that they use extensively, such as those given in Refs (1–3) for open-cup metal rotor Price-type meters.

10.1.1.2 Repair or replace meters which fall short of the specified spin duration.

10.1.2 For meters that are not amenable to spin testing, users must develop alternative tests for monitoring performance if such tests were not provided by the manufacturer under 7.1.5.5.

10.2 Examine the meters for obvious rotor dents or deformations after each use. Such rotor damage can affect the rating and may be an indicator of additional, less visible damage to the meter mechanism. Rotor replacement, repair or replacement of other parts, and recalibration, either alone or in some combination, will be required.

10.3 Examine the meters periodically during the course of a discharge measurement, for debris or damage which may affect performance of the meter, in addition to checks before and after use.

10.4 Provide instructions for routine maintenance, such as disassembly, cleaning, or lubrication after each use. Clean, lubricate, and check after each day's use, in default of more specific instructions. See Ref (1) for Price-type meter maintenance.

10.5 Make provisions to minimize wear on bearings or stress on other meter parts during transport and storage. Provide a suitable carrying case to protect the meter when not in use.

10.6 Field use and operational methods are described in Test Method D 3858.

## 11. Precision and Bias

11.1 Determination of the precision and bias for this test method is not possible, both at the multiple and single operator level, due to the high degree of instability of open channel flow. Both temporal and spatial variability of the boundary and flow conditions do not allow for a consent standard to be used for representative sampling. A minimum bias, measured under ideal conditions, is directly related to the bias of the equipment used and is listed in the following sections. A maximum precision and bias cannot be estimated due to the variability of the sources of potential errors listed in 11.3 and the temporal and spatial variability of open-channel flow. Any estimate of these errors could be very misleading to the user.

11.2 Under the allowances made in 1.5 of Practice D 2777 - 86, these precision and bias data do meet existing requirements for interlaboratory studies of Committee D-19 test methods. An exemption to the precision and bias statement required by D 2777 was recommended by the Results Advisor and concurred with by the Technical Operations Section of the D-19 Executive Subcommittee on June 15, 1990.

11.3 The towing-tank performance of an individually calibrated current meter can be described by its rating equation to within 1 % of the actual velocity with slightly higher deviations possible at the low velocities. However, in field use numerous error sources are recognized. The resulting errors have not been completely quantified but the following paragraphs are cited as possible sources of errors.

11.3.1 *Turbulence and Pulsations*—Current meters are usually calibrated by towing in still water but are used in turbulent flowing water. The effect of small scale (relative to cup size) turbulence on vertical axis meters has not been fully evaluated (5). Flows with obviously intense turbulent eddying shall be avoided where possible. Based on present knowledge, turbulence effects cannot be quantified but can be minimized with the use of a low inertia propeller-type meter with blades of high aspect ratio (square of the difference between outer diameter and hub diameter divided by blade area) (6).

11.3.2 *Platform Motions*—Guidelines on errors introduced by vertical motions, such as those associated with wave-induced boat motions, are given for selected vertical-axis and horizontal-axis meters in Ref (7). Generally these errors become more important with lower stream velocities.

11.3.3 *Velocity Gradients*—Cup-type vertical axis meters can be expected to over-register or under-register (with reference to the velocity at the axis) in the presence of a lateral velocity gradient, depending upon whether the velocity increases toward the open or closed face of the cup or drag element (8). Velocity-gradient effects on propeller-type meters have not been investigated.

11.3.4 *Boundaries*—Current meters can be affected by solid boundaries because of the flow gradients existing there and because of a direct proximity effect. Price and Pygmy-meter surface restrictions are cited in Ref (2). Proximity effects on propeller meters are generally less than those of vertical axis meters (9).

11.3.5 *Velocity Direction*—Current meters shall be oriented with the oncoming velocity filament to avoid misalignment errors. If a velocity component in another direction is required, the angle between the meter and the desired direction shall be measured independently and a cosine factor applied. Misalignment errors due to vertically angled flows cannot be corrected for in most meters. Price AA-type meters tend to underregister when the pitch angle with respect to the flow streamline exceeds 2.5 degrees (10). Flows with obvious vertically angled velocity filaments shall be avoided where possible (11). Exceptions are propeller meters equipped with component propellers (see 9.1.3).

11.3.6 *Temperature*—Response of some meters can be affected by temperature-induced viscosity changes in meter lubricating oil. See Ref (9) and 7.1.5.7.

11.3.7 The errors and uncertainties presented in 11.3 must be considered in addition to errors and uncertainties inherent in the rating equation.

## 12. Keywords

12.1 discharge measurement; open channel flow; water discharge; water velocity

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Technical Comments on ASTM D 3858-95

## Standard Test Method for Open-Channel Flow Measurement of Water by Velocity-Area Method

### Summary of ASTM D 3858-95

This ASTM method describes the equipment and protocol necessary to determine the volume flow rate (discharge) of water in an open channel. The velocity-area method involves dividing the channel into sections and measuring the velocity and cross-sectional area of each section. From these measurements, the discharge is calculated for each section, and the total discharge is determined by summing discharge results from each section.

### Additions Applicable to GJO Contractors and Their Subcontractors

The following sections shall be interpreted in conjunction with the current published version of the ASTM method. The sections shall be interpreted in numerical order, using the published version as the base document for reference.

### 9. Procedure

#### 9.1 Site Selection

9.1.1 Additional factors should be considered when selecting the section of stream to measure discharge.

9.1.2 Uniform flow within a single, well-defined, smooth channel is preferred with no overbank or underbank flow.

9.1.3 Avoid overhanging brush and submerged vegetation.

9.1.4 Avoid eddied, turbulent, and stagnant water.

13.3 The following information should be documented when making discharge measurements.

13.3.1 Manufacturer, model, and serial number of the current meter.

13.3.2 Current meter calibration information and date of calibration.

13.3.3 Count time of velocity measurements.

13.3.4 Date, time, units, locations, and magnitude of the velocity measurements.

13.3.5 Width and average depth of each section.

### 13. Quality Assurance

13.1 A duplicate velocity measurement should be collected and documented every 20 measurements as a check on measurement precision.

13.2 A duplicate discharge measurement should be collected and documented every 20 measurements as a check on method precision. The duplicate should be offset slightly from the original location.

### 14. Hazard Analysis

This method may involve personnel in or around potentially dangerous waterways that have an associated drowning hazard. If the task of measuring the discharge of a waterway is identified as a project requirement during the planning phase, then a hazard analysis will be conducted, and the appropriate precautions and safety equipment will be specified in the project health and safety plan. If the discharge measurement task was not anticipated at the start

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of the project, then a Job Safety Analysis will be conducted, and, if required, the appropriate precautions and required safety equipment will be specified in a Safe Work Permit.



# Standard Test Method for Open-Channel Flow Measurement of Water by Velocity-Area Method<sup>1</sup>

This standard is issued under the fixed designation D 3858; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the measurement of the volume rate of flow of water in open channels by determining the flow velocity and cross-sectional area and computing the discharge therefrom (Refs (1) through (7)).<sup>2</sup>

1.2 The procedures described in this test method are widely used by those responsible for the collection of streamflow data, for example, the U.S. Geological Survey, Bureau of Reclamation, U.S. Army Corps of Engineers, U.S. Department of Agriculture, Water Survey Canada, and many state and provincial agencies. The procedures are generally from internal documents of the above listed agencies, which have become the defacto standards as used in North America.

1.3 This test method covers the use of current meters to measure flow velocities. Discharge measurements may be made to establish isolated single values, or may be made in sets or in a series at various stages or water-level elevations to establish a stage-discharge relation at a site. In either case, the same test method is followed for obtaining field data and computation of discharge.

1.4 Measurements for the purpose of determining the discharge in efficiency tests of hydraulic turbines are specified in International Electrotechnical Commission Publication 41<sup>3</sup> for the field acceptance tests of hydraulic turbines, and are not included in this test method.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:

D 1129 Terminology Relating to Water<sup>4</sup>

D 2777 Practice for Determination of Precision and Bias of Applicable Methods of Committee D-19 on Water<sup>4</sup>

D 4409 Test Method for Velocity Measurements of Water in Open Channels with Rotating Element Current Meters<sup>4</sup>

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D-19 on Water and is the direct responsibility of Subcommittee D19.07 on Sediments, Geomorphology, and Open-Channel Flow.

Current edition approved Sept. 10, 1995. Published November 1995. Originally published as D 3858 - 79. Last previous edition D 3858 - 90.

<sup>2</sup> The boldface numbers in parentheses refer to the references listed at the end of this test method.

<sup>3</sup> For availability of this publication, contact the International Electrotechnical Commission, 3 rue de Varembe, CH 1211, Geneva 20, Switzerland.

<sup>4</sup> Annual Book of ASTM Standards, Vol 11.01.

D 5089 Test Method for Velocity Measurements of Water in Open Channels with Electromagnetic Current Meters<sup>4</sup>

### 2.2 ISO Standard:

ISO 3455 (1976) Calibration of Rotating-Element Current Meters in Straight Open Tanks<sup>5</sup>

## 3. Terminology

### 3.1 Descriptions of Terms Specific to This Standard:

3.1.1 *current meter*—an instrument used to measure, at a point, velocity of flowing water.

3.1.2 *discharge*—the volume of flow of water through a cross section in a unit of time, including any sediment or other solids that may be dissolved in or mixed with the water.

3.1.3 *float*—a buoyant article capable of staying suspended in or resting on the surface of a fluid; often used to mark the thread or trace of a flow line in a stream and to measure the magnitude of the flow velocity along that line.

3.1.4 *stage*—the height of a water surface above an established (or arbitrary) datum plane; also termed *gage height*.

3.2 *Definitions*—For definitions of terms used in this test method, refer to Terminology D 1129.

## 4. Summary of Test Method

4.1 The principal of this test method consists in effectively and accurately measuring the flow velocity and cross-sectional area of an open channel or stream. The total flow or discharge measurement is the summation of the products of partial areas of the flow cross section and their respective average velocities. The equation representing the computation is:

$$Q = \Sigma (av)$$

where:

$Q$  = total discharge,

$a$  = individual partial cross-sectional area, and

$v$  = corresponding mean velocity of the flow normal (perpendicular) to the partial area.

4.2 Because computation of total flow is a summation or integration process, the overall accuracy of the measurement is generally increased by increasing the number of partial cross sections. Generally 25 to 30 partial cross sections, even for extremely large channels, are adequate depending on the variability and complexity of the flow and the cross section. With a smooth cross section and uniform velocity distribution, fewer sections may be used. The partial sections should

<sup>5</sup> Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

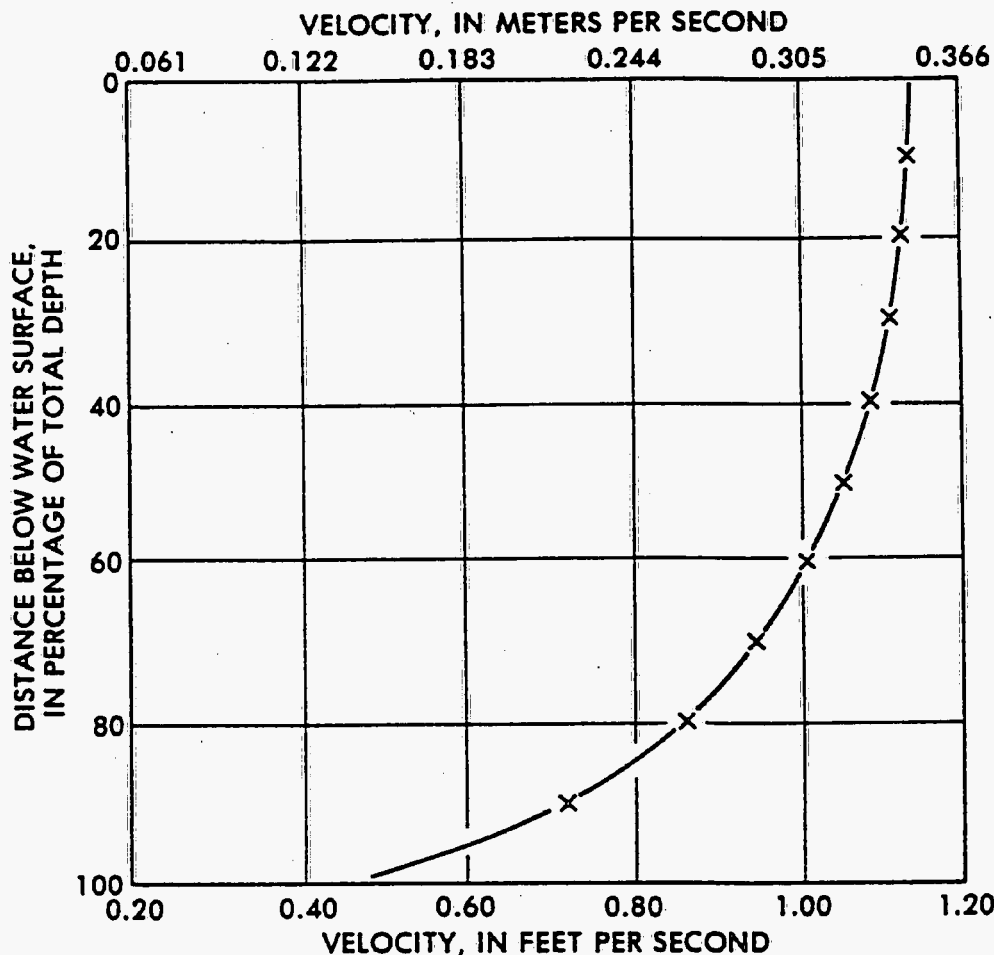


FIG. 1 Typical Open-Channel Vertical-Velocity Curve (Modified from Buchanan and Somers)<sup>6</sup>

be chosen so that each contains no more than about 5 % of the total discharge. No partial section shall contain more than 10 % of the total discharge.

NOTE 1—There is no universal “rule of thumb” that can be applied to fix the number of partial sections relative to the magnitude of flow, channel width, and channel depth because of the extreme variations in channel shape, size, roughness, and velocity distribution. Where a rating table or other estimate of total flow is available, this flow divided by 25 can serve as an estimate of the appropriate flow magnitude for each partial section.

4.3 Determination of the mean velocity in a given partial cross section is really a sampling process throughout the vertical extent of that section. The mean can be closely and satisfactorily approximated by making a few selected velocity observations and substituting these values in a known mathematical expression. The various recognized methods for determining mean velocity entail velocity observations at selected distances below the water surface. The depth selections may include choice of (1) enough points to define a vertical-velocity curve (see Fig. 1),<sup>6</sup> (2) two points (0.2 and 0.8 depth below water surface), (3) one point (0.6 depth), (4)

one point (0.2 depth), (5) three points (0.2, 0.6, and 0.8 depth), and (6) subsurface (that is, just below the water surface) (see 10.9 for further description of each method.)

## 5. Significance and Use

5.1 This test method is used to measure the volume rate of flow of water moving in rivers and streams and moving over or through large man-made structures. It can also be used to calibrate such measuring structures as dams and flumes. Measurements may be made from bridges, cableways, or boats; by wading; or through holes cut in an ice cover.

5.2 This test method is used in conjunction with determinations of physical, chemical, and biological quality and sediment loadings where the flow rate is a required parameter.

## 6. Apparatus

6.1 Many and varied pieces of equipment and instruments are needed in making a conventional discharge measurement. The magnitude of the velocity and discharge, location of the cross section, weather conditions, whether suspended, floating, or particulate matter are present in the water, and vegetative growth in the cross sections are all factors determining equipment needs. Instruments and equipment used normally include current-meters, width-

<sup>6</sup> Buchanan, T. J., and Somers, W. P., “Discharge Measurements at Gaging Stations,” *U.S. Geological Survey Techniques of Water-Resources Investigations*, Book 3, Chapter A8.

measuring equipment, depth-sounding equipment, timers, angle-measuring devices, and counting equipment. The apparatus is further described in the following paragraphs.

**6.1.1 Current Meter**—Current meters used to measure open-channel flow are usually of the rotating-element (see Note 2) or electromagnetic types. Refer to Test Methods D 4409 and D 5089 for more specific information. However, the equipment sections of this test method emphasize the rotating-element meters mainly because of their present widespread availability and use. The operation of these meters is based on proportionality between the velocity of the water and the resulting angular velocity of the meter rotor. Hence, by placing this instrument at a point in a stream and counting the number of revolutions of the rotor during a measured interval of time, the velocity of water at that point is determined. Rotating-element meters can generally be classified into two main types: those having vertical-axis rotors, and those having horizontal-axis rotors. The principal comparative characteristics of the two types may be summarized as follows: (1) the vertical-axis rotor with cups and vanes operates in lower velocities than does the horizontal-axis rotor, has bearings that are well protected from silty water, is repairable in the field without adversely affecting the meter rating, and works effectively over a wide range of velocities; (2) the horizontal-axis rotor with vanes disturbs the flow less than does the vertical-axis rotor because of axial symmetry with flow direction, and is less likely to be fouled by debris. Also, the rotor can be changed for different velocity ranges and meters of this type are more difficult to service and adjust in the field.

**NOTE 2**—Vertical-axis current meters commonly used are of the Price type and are available in two sizes, the large Price AA and the smaller Pygmy meter. The rotor assembly of the type AA is 5 in. (127 mm) and the Pygmy is 2 in. (51 mm) in diameter. The rotor assemblies of both meters are formed with 6 hollow metal or solid plastic cone-shaped cups.

The small Price pygmy meter is generally used when the average depth in a stream cross section is less than 1.5 ft (0.5 m) and velocity is below 2.5 ft/s (0.8 m/s). The large Price type meter should be used when average depths are greater than 1.5 ft (0.5 m). For high velocities, the large meter may be used for shallower depths. Do not change the meter if a few partial sections are outside these limits. In any case, meters should not be used closer to the streambed than 1.5 rotor or probe diameters.

Current meters used in the measurement of open-channel flow are exposed to damage and fouling by debris, ice, particulate matter, sediment, moss, and extreme temperature variations, and should be selected accordingly. Meters must be checked frequently during a discharge measurement to ensure that they have not been damaged or fouled.

**6.1.2 Counting Equipment**—The number of revolutions of a rotor in a rotating-element type current meter is obtained by an electrical circuit through a contact chamber in the meter. Contact points in the chamber are designed to complete an electrical circuit at selected frequencies of revolution. Contacts can be selected that will complete the circuit once every five revolutions, once per revolution, or twice per revolution of the rotor. The electrical impulse produces an audible click in a headphone or registers a unit on a counting device. The count rate is usually measured manually with a stopwatch, or automatically with a timing device built into the counter.

**6.1.3 Width-Measuring Equipment**—The horizontal dis-

tance to any point in a cross section is measured from an initial point on the stream bank. Cableways, highway bridges, or foot bridges used regularly in making discharge measurements are commonly marked with paint marks at the desired distance intervals. Steel tapes, metallic tapes, or premarked taglines are used for discharge measurements made from boats or unmarked bridges, or by wading. Where the stream channel or cross section is extremely wide, where no cableways or suitable bridges are available, or where it is impractical to string a tape or tagline, the distance from the initial point on the bank can be determined by optical or electrical distance meters, by stadia, or by triangulation to a boat or man located on the cross-section line.

**6.1.4 Depth-Sounding Equipment**—The depth of the stream below any water surface point in a cross section, and the relative depth position of the current meter in the vertical at that point, are usually measured by a rigid rod or by a sounding weight suspended on a cable. The selection of the proper weight is essential for the determination of the correct depth. A light weight will be carried downstream and incorrectly yield depth observations that are too large. A "rule of thumb" for the selection of proper sized weights is to use a weight slightly heavier in pounds than the product of depth (feet) times velocity (feet per second) (no direct metric conversion is available). The sounding cable is controlled from above the water surface either by a reel or by a handline. The depth-sounding equipment also serves as the position fixing and supporting mechanism for the current meter during velocity measurements. Sonic depth sounders are available but are usually not used in conjunction with a reel and sounding weight.

**6.1.5 Angle-Measuring Devices**—When the direction of flow is not at right angles to the cross section, the velocity vector normal to the cross section is needed for the correct determination of discharge. The velocity as measured by the current meter, multiplied by the cosine of the horizontal angle between the flow direction and a line perpendicular to the cross section, will give the velocity component normal to the measuring cross section. A series of horizontal angles and corresponding cosine values are usually indicated as a series of marked points on the measurement note form (standard form) or on a clipboard. The appropriate cosine value is then read directly by orienting the note form or clipboard with the direction of the cross section and the direction of flow. When measuring in deep swift streams, it is possible to sound the depth but the force of the current moves the weight and meter into positions downstream from the cross section; hence, the depths measured are too large (see Fig. 2).<sup>6</sup> Measurement of the vertical angle (between the displaced direction of the sounding line and the true vertical to the water surface) is necessary for computation of both air-line and wet-line corrections to the measured depth. A protractor for measuring vertical angles is considered to be special equipment which is available. Tables of air-line and wet-line corrections are also available. Tags or colored streamers placed on the sounding line at known distances above the center of the meter facilitate the measurement of depth, may eliminate the need for air-line corrections, and facilitate setting the meter at the proper depth.

**6.1.6 Miscellaneous Equipment**—The type and size of the equipment necessary to make a velocity-area discharge mea-

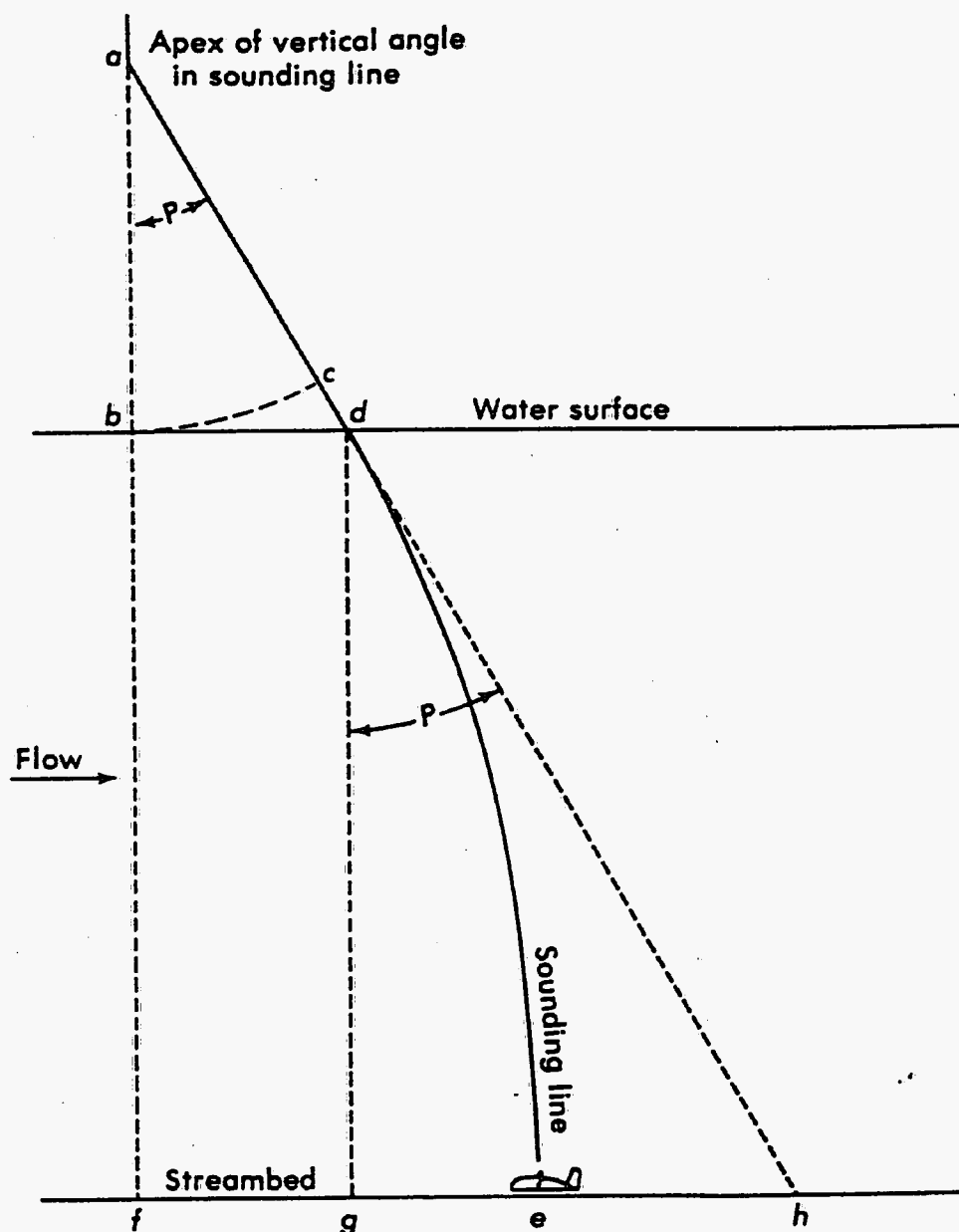


FIG. 2 Position of Sounding Weight and Line in Deep, Swift Water (from Buchanan and Somers)<sup>7</sup>

surement are extremely variable, depending on the magnitude of the discharge to be measured. Items such as sounding reels, streamlined sounding weights that range in size from 15 to 300 lb (6.8 to 136 kg), wading rods, handlines, taglines, etc., are available to measure discharges, velocities, and cross-sectional dimensions of almost any magnitude normally found in open-channel or stream settings.

## 7. Sampling

7.1 Sampling as defined in Terminology D 1129 is not applicable in this test method.

7.2 Make spatial sampling of velocity and flow in accordance with procedures and principles set forth in 4.2, 4.3, and 10.9

## 8. Calibration

8.1 To meet stipulated accuracy standards, it is necessary that rigid controls be established and observed in the manufacturing, care, and maintenance of current meters.

8.1.1 For all practical purposes, virtually all vertical-axis rotating-element meters of a specific type and manufacturer are identical. Some of the large organizations using these meters obtain rigid controls by supplying the production dies and fixtures and detailed specifications to manufacturers, so that identical properties are assured for each unit produced. The rating equations for the meters are nearly identical and a standard meter-rating table can be developed for each group of meters received from a common supply source.

8.2 Current-meter rating facilities have been constructed



for the purpose of developing quality control and uniformity in the whole current-meter rating procedure (see ISO 3455). In these rating facilities a current meter is "rated" by towing it through a long tank of still water. The meter is rigidly suspended from an electrically driven car that rides on rails precisely anchored along the top edges of the tank. The car is driven at precisely controlled speeds, for a large number of independent runs, to simulate a range of velocities representing those normally encountered in streamflow measurement.

## 9. Procedure

**9.1 Site Selection**—The selection of a suitable site for making a discharge measurement will greatly affect the accuracy of that measurement. The stream should be straight above and below the measuring section with the main thread of flow parallel to the banks. As a rule, the stream should be straight for at least three channel widths above and below the selected section. The streambed should be free of large rocks, piers, weeds, or other obstructions that will cause turbulence or create a vertical component in measured velocity. Water velocities and depths at the selected section must be consistent with capabilities of the equipment available for making the measurement.

**9.2 Current Meter Measurement by Wading**—Wading measurements usually are preferred if stream depth and velocity conditions permit. When the selection of a site is not dependent on an overhead structure this allows a wider range in choice of possible cross-section locations. Because the field person is in the water near his measuring equipment, he is in position to note changes in channel geometry, flow angles, obstructions which might effect flow patterns. In a wading measurement, the current meter is mounted on a wading rod in such a way that when the rod is held in a true vertical position, the meter is parallel to flow. The technician must stand in a position, usually to the side and slightly downstream from the rod, so that his body will not obstruct flow past the meter. As a "rule of thumb," wading measurements are unsafe when the product of water velocity (feet per second) times depth (feet) exceeds 10 (metres per second times depth in metres exceeds 1).

**9.3 Current Meter Measurement from Bridges**—Bridges are frequently used as a platform for making discharge measurements. Measurements from bridges are made by suspending the current meter on a handline or on a line attached to a sounding reel mounted on a bridge crane or bridge board. A sounding weight is suspended below the meter to hold it in position and as a method of obtaining the water depth. Measurements can be made from either the upstream or downstream sides of a bridge. The upstream side is generally preferred because the hydraulic characteristics of the bridge structure are less likely to affect the flow, streambed scour is less, and the presence of approaching drift in the stream is more visible. Advantages of the downstream side are that the need for horizontal-angle corrections to the flow vector may be minimized by the effects of the bridge-support structure. In situations where a bridge has a pedestrian walkway, that may offer a safer working environment. Older bridge alignments were generally perpendicular to streambanks to minimize the clear span; modern bridge alignments may cross streams at skewed angles or even on

curves. Such bridges are difficult to work from because of constantly changing horizontal-angle corrections.

**9.4 Current Meter Measurements from Cableways**—At sites where the frequency of discharge measurements is high, for example, as at a gaging station, a cableway may be erected to serve as a platform for measuring equipment and personnel. The advantage of a cableway is that it can be located at the most suitable hydraulic features on a stream. The meter and sounding weight are suspended by cable from a sounding reel in the same manner as from a bridge. Most cableways are built to accommodate hand-powered cablecars, to carry the field person across the stream. A few larger installations are equipped with gasoline-powered cablecars.

**9.5 Current Meter Measurements from Boats**—Small, lightweight boats, usually powered by outboard motors, are frequently used as a platform for making discharge measurements. Measurement sites can be selected on the basis of favorable hydraulic characteristics. Heavy taglines are usually attached to both streambanks to hold the boat in a cross section oriented perpendicular to the flow. Meter and sounding weight are suspended by cable attached to a boom extending over the bow of the boat, and data-collection procedures are similar to those used on bridges and cableways.

**9.6 Current Meter Measurements Under Ice Cover**—In regions where rivers freeze over during the winter, measurement of discharge through holes cut or drilled in the ice is common. Positioning of the current meter and the determination of water depth are most commonly obtained with a wading rod. For deep-swift-moving streams, cable suspension equipment is required. Sounding reels are mounted on specially designed sleds or stands and specially designed sounding weight hangers have been developed to pass through ice holes as small as 8 in. (200 mm) in diameter.

**9.6.1** The presence of an ice sheet on top of the water surface changes the way the water depth is computed. When an ice cover exists, it is necessary to compute the effective depth, that is, the depth of water beneath the ice cover. At holes cut with an ice chisel, chain saw, or ice drill, the total depth is measured from the water surface in the hole to the streambed. Then the distance from the water surface to the bottom of the ice layer is measured using an ice rod, L-shaped scale, or similar device. The effective depth is computed by subtracting the latter value from the total depth. In those cases where a thick slush layer exists below the ice cover, its thickness is determined by lowering the meter through it until it turns freely, then raising the meter until the rotor stops. The distance thus determined is then subtracted from the overall depth of water. The partial section area computation is made by multiplying the effective depth times the width, which is obtained in the same manner as is an open-water wading measurement.

**9.6.2** The presence of ice cover can have the effect of added channel roughness and resistance to flow. Therefore, the shape of the vertical-velocity profile is altered. When velocity is obtained by either the 0.2 and 0.8 depth method or by measuring the vertical-velocity profile, the observations are used as in an open-water measurement. However, if the 0.6 depth method is used, a coefficient of 0.92 is applied to the velocity observations to adjust for the added resistance of the ice sheet. An acceptable alternate procedure is to obtain a

velocity observation at 0.5 depth and apply a coefficient of 0.88.

## 10. Calculation

10.1 In the velocity-area method of making a discharge measurement it is assumed that the velocity sample for each partial cross section represents the mean velocity in that section. The lateral extent of a given partial cross-section spans half the distance toward the preceding meter location and half the distance toward the next meter location. The vertical extent is from the streambed to the water surface at the vertical in which the meter is located. Observations of velocity are normally made along with measurements of the sounded depth.

10.2 The total flow cross section (see Fig. 3) is defined by depths at locations 1, 2, 3, 4, 5, ...  $n$ . At each of these locations the mean of the vertical distribution of velocity is approximated to the desired accuracy through a selected sampling technique of current-meter measurements. The discharge for the partial cross section at location  $x$  is then computed as:

$q_x$  = discharge through partial section  $x$ ,  
 $v_x$  = mean velocity at location  $x$ ,  
 $b_x$  = distance from initial point to location  $x$ ,  
 $b_{(x+1)}$  = distance from initial point to center of next partial section, and  
 $d_x$  = water depth at location  $x$ .

Hence, the partial stream discharge through partial section 4 (heavily outlined in Fig. 3) is computed as:

$$q_4 = v_4 \left[ \frac{b_5 - b_3}{2} \right] d_4$$

10.3 Discharge computations at the end sections shown in Fig. 4 differ slightly in that there is no "preceding location" at location 1 and no "next location" at location  $n$ . Therefore,

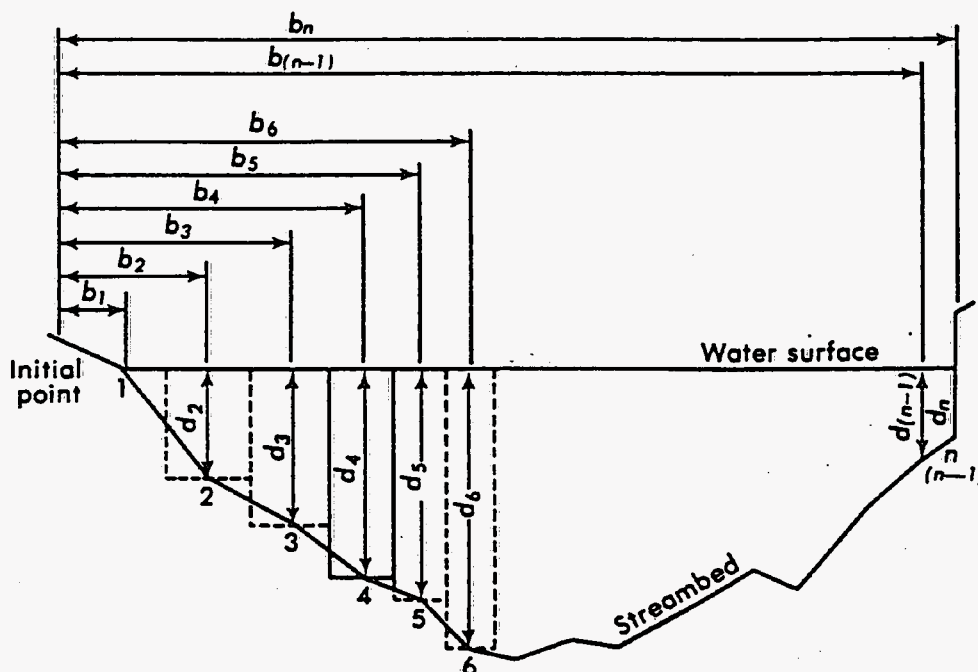
$$q_1 = v_1 \left[ \frac{b_2 - b_1}{2} \right] d_1$$

$$q_n = v_n \left[ \frac{b_n - b_{(n-1)}}{2} \right] d_n$$

However,  $d_1$  is zero in the example and therefore  $q_1$  must also be zero. The depth at location  $n$  is shown as a finite vertical distance, which could occur at canal walls or at bridge piers and abutments. Because it is impossible to

$$q_x = v_x \left[ \frac{b_x - b_{(x-1)}}{2} \right] + \left[ \frac{b_{(x+1)} - b_x}{2} \right] d_x = v_x \left[ \frac{b_{(x+1)} - b_{(x-1)}}{2} \right] d_x$$

where:



### EXPLANATION

- 1,2,3..... $n$  Observation points
- $b_1, b_2, b_3$ ..... $b_n$  Distance, in feet, from the initial point to the observation point
- $d_1, d_2, d_3$ ..... $d_n$  Depth of water, in feet, at the observation point
- Dashed lines Boundary of partial sections; one heavily outlined discussed in text

FIG. 3 Definition Sketch of Midsection Method of Computing Cross-Section Area for Discharge Measurements (from Buchanan and Somers)?

obtain a current-meter velocity measurement exactly at location  $n$ , the velocity is usually estimated as a percentage of the velocity measured at the preceding section. A "rule of thumb" for selection of this correction is 85 to 95 %, depending on the roughness of the structure and the observed effect on the flowlines. End sections should therefore be chosen to have small widths.

10.4 In case of narrow streams, the horizontal spacing of partial sections is partially dependent on the width of the current meter. Normal minimum section spacing for Type AA Price meters is 0.5 ft (150 mm) and for the Pygmy meter 0.2 ft (60 mm). For exceptionally small measuring sections, where the total channel width is about 2 ft (0.6 m) or less, section spacing as close as 0.1 ft (30 mm) improves the accuracy of the measurement.

10.5 The summation of the discharges for all of the partial sections is the total discharge of the stream.

10.6 In order to determine the velocity at a point with a current meter, it is necessary to immerse the meter at that point for a measured interval of time, usually 40 to 70 s. Do not begin timing until disturbances caused by inserting the meter have subsided. It is then necessary for the measurement process to span a period of time that is long enough to smooth and average out transient velocity fluctuations. When the timing interval is completed, the velocity value is found from a meter-rating table for the particular meter. Refer to Test Method D 4409 for guidelines on checking performance of rotating element current meters.

10.7 Periodically remove the current meter from the water for examination during the measurement, usually when moving from one vertical location to another.

10.8 Take care to ensure that the current-meter velocity observations are not affected by upstream obstructions in the channel, random surface waves, and wind.

10.9 As stated in 4.3, there are various recognized methods of measuring the mean velocity in a vertical. Each method has its merits depending on the time available to make the measurement, the width of the stream cross section and depth of water, the streambed roughness, whether the stage is changing, whether the flow is steady or unsteady, and type of current-meter suspension. Some of the relative merits and uses of the various methods are as follows:

10.9.1 The vertical-velocity curve method for determining a mean velocity value (see Fig. 1) normally requires averaging velocity readings taken at 0.1 depth increments over the interval between 0.1 to 0.9 of the depth. This method is valuable in determining coefficients for application to results of other methods. Generally, however, it is not used for routine discharge measurements because of the large amount of time required to collect nine velocity readings in each vertical in order to compute each mean velocity.

10.9.2 The two-point depth method (0.2 and 0.8 depth below the water surface) averages the velocities observed at these two depths in a vertical and this average is used as the mean velocity for that vertical. A rough test of whether or not the velocities at the 0.2 and 0.8 depths are sufficient for determining the mean vertical velocity is given in the following criterion: the 0.2-depth velocity should be greater than the 0.8-depth velocity but no more than twice as great. If this test is not met then the 3-point depth method should be used. Experience has shown that this method gives more

consistent and accurate results than any of the other methods except the vertical-velocity curve method. The two-point depth method generally is not used at depths less than 2.5 ft (0.76 m) because the settings for a large rotating element meter or 1.5 ft (0.46 m) for the pygmy meter would be too close to the water surface and streambed for dependable results.

10.9.3 The six-tenths depth method (0.6 depth below water surface) uses the observed velocity at this depth as the mean velocity in the vertical. This method gives reliable results whenever the water depth is too shallow for application of the two-point depth method, whenever large amounts of slush ice or debris prevent observation of the 0.2 depth velocity for the two-point depth method, or whenever the stage or flow is changing rapidly and a measurement must be made quickly.

10.9.4 The two-tenths depth method (0.2 depth below water surface) uses the observed velocity at this depth, multiplied by a coefficient, to obtain a value for the mean in the vertical. This method is used mainly during periods of extremely high flow when the velocities are great, making it impossible to obtain reliable velocity measurements at the 0.8 or 0.6 depth. A general knowledge of the cross section, the relative depths with stage, and the vertical-velocity curve at the location are needed if it is impossible to obtain reliable depth soundings. A coefficient of about 0.87 is typically used as the multiplier for the velocity readings. A sizeable error in the assumed 0.2 depth is not critical to accuracy because the vertical-velocity curve at this point is usually nearly vertical. Normally, the two-point and six-tenths depth methods are preferred to this method because of their greater accuracy.

10.9.5 The three-point depth method consists of measuring the velocity at 0.2, 0.6, and 0.8 of the depth, thereby combining the two-point and six-tenths depth methods. The mean velocity is obtained by averaging the 0.2 and 0.8 depth observations and then averaging this result with the 0.6 depth measurement. This method is used when the velocities in the vertical are abnormally distributed. The depths must exceed 2.5 ft (0.86 m) before this method is used, if the measurements are being made with large rotating-element current meters.

10.9.6 The subsurface method of velocity determination observes the velocity at some small distance below the water surface and converts this velocity determination to a mean velocity in the vertical through the use of a coefficient of 0.86. The observation of velocity should be far enough below the water surface to avoid the effect of surface disturbances. This method is used when it is impossible to obtain reliable depth soundings.

10.9.7 The surface method has limited use but is appropriate in such events as major floods. Floating debris or ice is simply timed over a known or estimated distance. In these circumstances, a knowledge of the vertical-velocity curve at the location and a reliable estimate of an applicable coefficient is needed to convert a surface velocity to a mean velocity in the vertical. A coefficient of about 0.85 is commonly used. The surface or float method is appropriate when it is impossible to use a current meter because of excessive velocities and depths, or where velocities and depths are too low for a current-meter measurement.

## 11. Precision and Bias

11.1 Determination of the precision and bias for this test method is not possible, both at the multiple and single operator level, due to the high degree of instability of open channel flow. Both temporal and spatial variability of the boundary and flow conditions do not allow for a consent standard to be used for representative sampling. A minimum bias, measured under ideal conditions, is directly related to the bias of the equipment used and is listed in the following sections. A maximum precision and bias cannot be estimated due to the variability of the sources of potential errors listed in 11.3 and the temporal and spatial variability of open channel flow. Any estimate of these errors could be very misleading to the user.

11.2 In accordance with 1.6 of Practice D 2777, an exemption to the precision and bias statement required by Practice D 2777 was recommended by the results advisor and concurred with by the Technical Operations Section of the Committee D-19 Executive Subcommittee on June 7, 1989.

11.3 The accuracy of a flow measurement by the velocity-area method is directly related to the following:

11.3.1 The accuracy in the total and section width measurements. Where the measurement of the width between verticals is normally based on distance measurements from a reference point on the bank, the error is usually negligible. Normally, width measurements are made and recorded to 1 ft (300 mm) units, except when partial section widths are less than 1 ft (300 mm) in which case measurements to 0.1 ft (30 mm) units are used. Where the measurements are by optical means, the errors will depend on the distance magnitudes and equipment used.

11.3.2 The errors in measuring the depths relate to both individual soundings and readings of the water level. These errors can be extremely variable depending on the depth and roughness of the channel, velocity of flow, stability of the bed materials, roughness of the water surface, distance of observer above the water surface, and adequacy of sounding weights. When discharge measurements are made by cable suspension from bridges or cableways, depth observations are generally recorded to 0.1 ft (30 mm). For wading measurements, where the depths are small and the techni-

cian is close to the equipment, depth readings to 0.02 ft (6 mm) to 0.05 ft (15 mm) are possible.

11.3.3 The errors in determining point velocities in a vertical will depend on the accuracy of the measuring equipment (current meter), the method used for velocity measurement (see 10.9), the accuracy in placement of the current meter, the duration of the velocity sampling period, closeness to boundaries, and the irregularity of the velocity distribution in time and space. Meters should not be used to sense velocities outside their calibration limits. Velocity observations are generally recorded to two decimal places, in feet per second (5.28 ft/s or 1.61 m/s), except at extremely low flow, where three-decimal accuracy may be used (0.233 ft/s or 0.068 m/s).

11.3.4 The overall errors in determining stream discharge by the velocity area method relate particularly to the choice of the number of verticals and to the number of measurement points in each vertical. Errors will also depend on the width of channel, the ratio of width to depth, the method of computation used, and the irregularity of stream velocity in time and space. Measured discharge is generally calculated to three-significant figure accuracy.<sup>7</sup>

11.3.5 It has been shown that discharge measurements having 30 partial sections and using the two-point depth method of observation, with a 45-s period of observation, will have a standard error of 2.2 %. This means that two thirds of the measurements made using this procedure would be in error by 2.2 % or less. It has also been shown that the standard error is 4.2 % for a 25-s period of observation, using the 0.6 depth method of velocity observations, with depth and velocity observed at 16 partial sections. The error caused by using the latter shortcut method is generally less than the error that can be expected by shifting of flow patterns during periods of rapidly changing stage.

## 12. Keywords

12.1 discharge measurement; open channel flow; water discharge

<sup>7</sup> Carter, R. W., and Anderson, I. E., "Accuracy of Current-Meter Measurements," *Journal of the Hydraulics Division—Proceedings of the American Society of Civil Engineers*, Vol 89, No. HY 4, July 1963, American Society of Civil Engineers, pp. 105-115.



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- (4) U.S. Bureau of Reclamation, *Water Measurement Manual*, Second Edition Revised Reprint 1974, U.S. Government Printing Office, 1974.
- (5) Rantz, S. E., "Measurement and Computation of Streamflow," *Measurement of Stage and Discharge*, Vol I, Water Supply Paper 2175, 1982.
- (6) *ISO Standard 748-1979E*—Measurement of Liquid Flow in Open Channels, International Standards Organization, 1979.
- (7) *National Handbook of Recommended Methods for Water Data Acquisition*, U.S. Geological Survey, 1977.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, are entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

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# Standard Practice for Preparing or Revising Procedures for the *GJO Environmental Procedures Catalog*

## 1. Scope

1.1 This practice describes the preparation, review, approval, and distribution of procedures in the *GJO Environmental Procedures Catalog* (GJO 6).

1.2 The procedures in this catalog are not intended to address all of the details and variations that might apply to an individual project. Therefore, a site-specific plan or other project-specific document will describe in detail the work that will be performed and will identify procedures from the *GJO Environmental Procedures Catalog* (GJO6) that will be used.

## 2. Hazard Analysis

2.1 No hazards requiring controls have been identified. Site-specific controls are available in the Health and Safety Plan for a particular project.

## 3. Referenced Documents

3.1 American Society for Testing and Materials (ASTM), *Form and Style for ASTM Standards*, 10th Edition, Philadelphia, PA, August 1997

3.2 *GJO Environmental Procedures Catalog* (GJO 6): Procedure GA-3(P), "Standard Practice for Quality Assurance"

3.3 *GJO Training Manual* (GJO 4): Section 8.0, "Environmental Qualification Procedure"

## 4. Responsibilities

4.1 Technical Manager, MACTEC-ERS Geosciences has overall responsibility for the *GJO Environmental Procedures Catalog* (GJO 6) as defined by Task Order which includes management of the catalog and implementation of the qualification system as defined in Section 8.0 of GJO 4.

4.2 Environmental Procedures Advisory Committee (EPAC)—A combined FOS/TAR contractor group of professionals with expertise

in particular areas who serve as advisors to address questions and problems relevant to the *GJO Environmental Procedures Catalog* (GJO 6) and the associated training.

4.3 EPAC Catalog/Training Coordinator is the point contact for procedure revisions and distribution. The current electronic and paper versions of each procedure are maintained by the catalog coordinator. The coordinator also maintains the training qualifications and provides input to the Training Information System.

4.4 EPAC Technical Leads manage a section of the catalog. Their duties include assigning a key proficient person to each of the procedures, oversight for revisions to and reviews of procedures, and approval of project-specific changes to procedures.

## 5. Terminology

5.1 *Acceptance criteria*—Specified limits, requirements, or tolerances placed on the variation permitted in the characteristics of an item, process, report, data, or service as defined in codes, standards, drawings, specifications, procurement documents, or other requirements documents. The criteria must be definitive for decision-making purposes but might not be related to instruments or measurements.

5.2 *Environmental Procedures Advisory Committee (EPAC)*—See paragraph 4.2.

5.3 *Guide*—A procedure that outlines a suggested approach through a series of options or instructions but does not recommend a specific course of action.

5.4 *May*—In procedures, a suggestion only.

5.5 *Must*—In procedures, a required action. Synonymous with "shall" and "will".

5.6 *Planning document*—A document prepared to guide a project or task. These documents may be called Work Plans, Sample and Analysis Plans,



project plans, or task plans, depending on sponsor requirements.

**5.7 Practice**—A definitive procedure for performing one or more specific operations or functions that does not produce a test result.

**5.8 Procedure**—Steps to perform, explain, or accomplish a task. As used in this catalog, a procedure may be a practice, guide, or test method.

**5.9 Qualified**—An employee who has met the requirements for a specific position or task.

**5.10 Shall**—In procedures, a required action. Synonymous with “must” and “will”.

**5.11 Should**—In procedures, a recommendation.

**5.12 Test method**—A definitive procedure for the identification, measurement, and evaluation of one or more characteristics of a material, product, system, or service that produces a test result.

**5.13 Training Information System**—A central database providing an electronic record of personnel training.

**5.14 Will**—In procedures, a required action. Synonymous with “must” and “shall”.

## 6. Significance and Use

**6.1** The catalog is intended to be a source of information that may be used with the minimum administrative burden that is consistent with control of activities. The procedures may be used as written or they may be modified by the method discussed in Section 8 “Changes to Procedures.”

**6.2** This practice is for use by any personnel preparing procedures for the GJO *Environmental Procedures Catalog* (GJO 6). From the standpoint of technical accuracy, this practice will ensure that procedures are complete and scientifically sound. From the standpoint of usability, the practice will ensure that procedures are uniform and will help the user find information easily and understand it quickly.

**6.3** All new, revised, or adopted procedures in this catalog will adhere to this practice.

## 7. New Procedures

**7.1** New procedures may be needed to support new work, changes in work scope, new technology or instruments, or improved methods. When the need for a procedure to be added to the catalog is known, the EPAC will review the suggested procedure to determine if it is appropriate for inclusion.

**7.2 Types of Procedures**—Three categories of procedures are defined for this catalog on the basis of ASTM guidelines. These categories are practices, guides, and test methods. Development of the text will be based on the determination of which of these three categories best describes the procedure being prepared. Other types of procedures defined in ASTM may be used, if more appropriate. See reference 3.1, for more information.

**7.2.1** Examples of practices include selection, preparation, application, inspection, necessary precautions for use or disposal, installation, maintenance, and operation of testing apparatus. Examples of guides include reference lists, general considerations, and glossaries. The following list describes headings to be included in a practice or guide. See reference 3.1, for more detailed information on practices and guides.

Title (mandatory)  
Scope (mandatory)  
Hazard Analysis (mandatory)  
Referenced Documents  
Terminology  
Summary of Practice (or Guide)  
Significance and Use (mandatory)  
Reagents (including materials or equipment)  
Procedure  
Report  
Precision and Bias (for included tests and analyses)  
Keywords (mandatory)  
Annexes and Appendices

**7.2.2** Examples of test methods include determination of fundamental properties of materials and a variety of field and laboratory analytical or measurement procedures. The following list describes headings to be included in a test method. See reference 3.1, for more detailed information on test methods.

Title (mandatory)  
 Introduction  
 Scope (mandatory)  
 Hazard Analysis (mandatory)  
 Referenced Documents  
 Terminology  
 Summary of Test Method  
 Significance and Use (mandatory)  
 Interferences  
 Apparatus (includes equipment)  
 Reagents and Materials  
 Sampling, Test Specimens, and Test Units  
 Preparation of Apparatus  
 Calibration and Standardization  
 Conditioning  
 Procedure (mandatory)  
 Calculation or Interpretation of Results  
 Report  
 Precision and Bias (mandatory)  
 Keywords (mandatory)  
 Annexes and Appendices

7.3 Procedures will adequately describe the work so that a qualified person could use the procedure to perform work. The procedure will describe responsibilities and interfaces, delineate the method and sequence, and provide a means of recording data when appropriate. Acceptance criteria will be identified when applicable.

7.3.1 Additional quality assurance concerns for procedures are available in Procedure GA-3(P), "Standard Practice for Quality Assurance".

7.4 Each procedure shall contain a section titled "Hazard Analysis," that identifies each potential hazard inherent to performance of the procedure.

7.4.1 Each procedure shall identify the potential hazards on a Hazards Identification Chart (Figure 1) by marking those hazards with a "Y" in the "Y/N" column. Hazard evaluation should not include site-specific hazards such as heat stress or contamination; these hazards are addressed in site-specific Health and Safety Plans.

7.4.1.1 For each hazard, the need for controls and the level of risk involved in performing the procedure shall be evaluated. Each hazard and any action necessary to implement a control shall be specified as a separate paragraph in this section.

7.4.2 The completed Hazards Identification Chart will be included in the procedure review package. The chart should not be included as part of the procedure. The chart is intended to assist reviewers in independently evaluating the procedure.

7.4.3 If no hazards requiring controls are identified, the Hazard Analysis section should contain the following text: "No hazards requiring controls have been identified. Site-specific controls are available in the Health and Safety Plan for a particular project."

7.5 *Procedure Format*—The format of procedures will follow the *Form and Style for American Society for Testing and Materials (ASTM) Standards*, reference 3.1, as amended by this procedure. When preparing procedures, the modified decimal numbering system (see reference 3.1) will be used to number divisions in the text. The divisions are numbered to show subordination of items within a section (e.g., 1., 1.1, 1.1.1, and 1.1.1.1 show the order of subordination).

## 7.6 *Miscellaneous Points of Style*

7.6.1 *Units of Measure*—Consistent units of measure will be used throughout the procedure. Units of measure are always spelled out the first time they appear in the text and any time they are not preceded by a value.

7.6.2 *Uppercase Letters*—**Do not** use uppercase letters when writing text or numbered text headings (e.g., "5.5.9 *Uppercase Letters*," not "5.5.9 UPPERCASE LETTERS"). Use of all uppercase letters is acceptable in trade names, equations, variables, etc.

7.7 Text should be provided to the coordinator of the catalog on disk or by e-mail. The disk should be accompanied by a printed copy of the text and all figures or forms to be included in the procedure. The coordinator will ensure that the procedure is in the proper format, assign the procedure number, coordinate reviews, and assist in comment resolution.

## HAZARDS IDENTIFICATION CHART

Procedure No. LQ-17 Date 12/1/98 Performed By Joe King

The following hazards shall be considered. The list may not be complete. Add any other identified hazard to the list. On an attached page describe each identified hazard along with controls needed.

| Potential Hazard                 | Y/N      | Potential Hazard                  | Y/N      |
|----------------------------------|----------|-----------------------------------|----------|
| <b>Electrical Sources</b>        |          | <b>Heat Sources</b>               |          |
| Capacitors .....                 | _____    | Electrical .....                  | <u>Y</u> |
| Transformers .....               | _____    | Steam .....                       | _____    |
| Batteries .....                  | _____    | Flames .....                      | _____    |
| Exposed Conductors .....         | _____    | Solar .....                       | _____    |
| Static Electricity .....         | <u>Y</u> | Friction .....                    | _____    |
| Underground Utilities .....      | _____    | Spontaneous Combustion .....      | _____    |
| Other High Voltage .....         | _____    | <b>Cold Sources</b>               |          |
| <b>Motion Sources</b>            |          | Cryogenic Materials .....         | _____    |
| Pulley Belt .....                | _____    | Ice, Snow, Wind, Rain .....       | _____    |
| Gear .....                       | _____    | <b>Radiant Sources</b>            |          |
| Shears .....                     | _____    | Intense Light .....               | _____    |
| Sharp Edges .....                | _____    | Lasers .....                      | _____    |
| Pinch Points .....               | _____    | Ultraviolet (UV) .....            | _____    |
| Vehicles .....                   | _____    | X-rays, Ionizing Radiation .....  | _____    |
| Mass in Motion .....             | <u>Y</u> | Infrared Sources .....            | _____    |
| Rotating Equipment .....         | _____    | Electron Beams .....              | _____    |
| <b>Gravity-Mass Sources</b>      |          | Magnetic Fields .....             | _____    |
| Personnel Falling .....          | _____    | RF Fields, Microwave, Radar ..... | _____    |
| Falling Object .....             | _____    | <b>Other Hazards</b>              |          |
| Lifting .....                    | <u>Y</u> | <u>Noise hazards due</u>          |          |
| Tripping, Slipping .....         | _____    | <u>to generator.</u>              |          |
| Earthquake .....                 | _____    | _____                             |          |
| <b>Pressure Sources</b>          |          | _____                             |          |
| Confined Gases .....             | <u>Y</u> | _____                             |          |
| Explosives .....                 | _____    | _____                             |          |
| Noise .....                      | _____    | _____                             |          |
| Chemical Reactions .....         | _____    | _____                             |          |
| Stressed Mechanical System ..... | _____    | _____                             |          |
| <b>Chemical Sources</b>          |          | _____                             |          |
| Corrosive Materials .....        | _____    | _____                             |          |
| Flammable Materials .....        | <u>Y</u> | _____                             |          |
| Toxic Materials .....            | _____    | _____                             |          |
| Radioactive Materials .....      | _____    | _____                             |          |
| Pathogenic Materials .....       | _____    | _____                             |          |
| Oxygen Deficiency .....          | _____    | _____                             |          |
| Carcinogenic Materials .....     | _____    | _____                             |          |

Figure 1. Example of a Hazards Identification Chart

**7.8 Procedure Numbering**—Procedures in this catalog will be assigned a number in the following format: XX-N(A)

where:

- XX = GA (General Administrative chapter)  
 GT (General Technical chapter)  
 SL (Solids chapter)  
 LQ (Liquids chapter)  
 GS (Gases chapter)  
 GP (Geophysical Measurements chapter)  
 RD (Radiological Measurements chapter)
- N = The sequential number of the procedure within the chapter
- (A) = Type of procedure: Practice (P), Guide (G), or Test Method (T).

7.8.1 For example, General Considerations for the Sampling of Liquids is the first procedure in the Liquids chapter and is numbered LQ-1(G).

7.8.2 The procedure number is indicated on the upper right-hand corner of each odd-numbered page. (This position is reversed on even-numbered pages.)

**7.9 Procedure Date and Revision**—The date and revision number of the procedure are indicated immediately below the procedure number. The date will appear in month and year format with the revision number directly following. For example, 1/91 Rev. 0 was issued in January 1991 and is the initial version.

7.10 "GJO" will appear on the upper left-hand corner of each odd-numbered page. (This position is reversed on even-numbered pages.)

7.11 The catalog coordinator should be contacted for questions regarding new procedures.

## 8. Changes to Procedures

**8.1 Changes to Existing Catalog Procedures**—When changes to a procedure are required, the originator shall submit a hard copy and/or electronic copy of the proposed revision to the catalog coordinator. For questions, contact the catalog coordinator.

8.1.1 If only editorial changes are needed, and the changes do not affect the safety or the quality of work performed or data generated, the changes may be made without going through the formal reviews that are required for technical changes; however, the changes must be approved by the EPAC Chair. A procedure for which only editorial changes are implemented will be given a new revision number and a new date. When such a procedure is distributed, it should be accompanied by a statement that the changes are editorial only.

**8.2 Project-Specific Changes to Procedures**—Changes to a procedure might become necessary during project planning or during field operations. Records of review and approval for these changes will be included in the project records. These changes should be considered for incorporation in the *GJO Environmental Procedures Catalog* (GJO 6) if the same changes are made repeatedly.

8.2.1 Procedures from this catalog that will be used on a specific project in planning documents should be identified in those documents. Modification of a catalog procedure made during planning for the project will be through an addendum that is documented on the Document Addition/Revision form (Figure 2) and approved by the Project Manager.

8.2.2 Changes that are needed during field operations will be documented in the field log and on the Document Addition/Revision form. The documented changes and a copy of the procedure will be given to the Project Manager or designee for review and approval. The review must include a technical review by the original author or reviewers who have comparable technical knowledge. The approval will be documented on the Document Addition/Revision form and appended to the procedures that are used in the field.

8.2.3 The Project Manager is responsible for evaluating each revision of a catalog procedure included as part of the project documents to determine if the revised procedure should replace the version that is currently in use for that project.

**8.3 Adopting Industry-Recognized Procedures**—When possible, programs should use existing industry-recognized procedures with an addendum rather than write new procedures

**Environmental Procedures Catalog  
Document Addition/Revision**

Procedure Title RD-4(T)  
Requester Joe King  
Justification Procedure Update

Proposed Changes (list here or attach copies)

See attached

- ☐ New Document  
☒ Change to Procedure  
☐ Adopt Procedure

Approval for Inclusion in *Environmental Procedures Catalog*

Procedure Number Assigned

*Environmental Procedures Advisory Committee Chair*

*Date*

Project-Specific Change for

*Project*

Reviewed  
by

*Technical Author or  
Proficient Person*

*Date*

Approved by

*Manager or Designee*

*Date*

Effective Date

Figure 2. Example of a Document Addition/Revision Form

for the catalog. The addendum will be titled "Technical Comments on (industry procedure number and title)" and shall include references to the numbered sections in the existing procedure that are being modified. A separate Hazard Analysis section and, as appropriate, specific sources of required equipment or supplies and quality assurance requirements should be added to the addendum. Any added sections will be numbered sequentially starting with the number following the last section of the industry procedure.

8.3.1 Industry-recognized procedures from source documents published by the U.S. Environmental Protection Agency, ASTM, U.S. Department of the Interior, National Water Well Association, American Petroleum Institute, or other recognized organizations should be used, if possible. Permission from the sponsoring agency, such as ASTM may be required to produce and distribute the procedure.

## **9. Procedure Review, Publication, Approval, and Distribution**

9.1 *Procedure Review*—Each new, revised, or adopted procedure in this catalog will be sent to qualified technical individuals and personnel from environmental, safety, and quality groups for review. Editorial changes, as described in Section 8.1.1 require review only by the EPAC Chair.

9.1.1 The catalog coordinator sends a copy of the procedure along with a Record of Review form (see Figure 3 for front page) and Hazards Identification Chart (for new procedures) to each reviewer. Comments must be resolved by the author and/or coordinator before submitting the procedure for publication.

9.2 *Publication of Procedures*—The catalog coordinator arranges for production of additions or changes to the catalog.

9.2.1 Release of each revision to the catalog will require issuing a new table of contents. The table of contents lists each procedure within a chapter and the current date and revision number.

9.2.2 Change bars indicate revised material in the procedures and table of contents.

9.3 *Procedure Approval*—A copy of the final procedure along with a completed Document

Addition/Revision form is submitted to the EPAC Chair for approval before the procedure is released and distributed. A record of the approval will be maintained by the catalog coordinator.

9.4 *Distribution of Procedures*—The catalog coordinator, in cooperation with the Contractor Document Control Specialist, will distribute copies of the catalog to library locations on the distribution list.

## **10. Procedure Access**

10.1 Procedures may be copied directly from the catalog, marked as "*Uncontrolled Copy*", and inserted into other documents, such as Sampling and Analysis Plans. Catalog procedures may be identified in the documents by reference only; however, it is recommended that they be physically attached to the documents.

## **11. Records**

11.1 A historical hard copy of each version (revision) of each procedure will be maintained by the EPAC Catalog/Training Coordinator. Records of review and comment resolution will be maintained for the current version of each procedure; such records of previous versions may be destroyed.

## **12. Keywords**

12.1 ASTM, guide, hazard analysis, practice, procedure, review, and test method.

## Record of Review

| Due Date<br>02/24/97                                                                                                                                            | Review No.                                                                                                        | Project:<br>EPAC | Type of Review<br>Comprehensive                                                                                                                                                                                                                          | Page <u>1</u> of <u>1</u>       |                   |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|-------------------|
| Document Title and/or Number and Revision:<br><br>RD-4(T), Rev., Standard Test Method for Radium-in-Soil Sample Analysis Using the Opposed Crystal System (OCS) |                                                                                                                   |                  | Reviewers Recommendation<br><br><input type="checkbox"/> Release Without Comment<br><input type="checkbox"/> Consider Comments<br><input type="checkbox"/> Resolve Comments and Reroute for Review<br><br>_____<br><i>Signature of Reviewer and Date</i> |                                 |                   |
| Author<br>Cathy Kelleher (Return to Kym Bevan)                                                                                                                  |                                                                                                                   |                  | <input checked="" type="checkbox"/> Comments Have Been Addressed<br><br>_____<br><i>Signature of Author and Date</i>                                                                                                                                     |                                 |                   |
| Author's Organization                                                                                                                                           |                                                                                                                   | Author's Phone   | <input type="checkbox"/> Comments Resolution Satisfactory<br><input type="checkbox"/> Comments Resolution Unsatisfactory<br><br>_____<br><i>Signature of Reviewer and Date</i>                                                                           |                                 |                   |
| Reviewers: Joe Blow                                                                                                                                             |                                                                                                                   |                  |                                                                                                                                                                                                                                                          |                                 |                   |
| Reviewer's Organization<br>Quality Assurance                                                                                                                    |                                                                                                                   | Reviewer's Phone |                                                                                                                                                                                                                                                          |                                 |                   |
| Item No.                                                                                                                                                        | Reviewer's Comments and Recommendation                                                                            | Reqd. (Y/N)      | Item No.                                                                                                                                                                                                                                                 | Author's Response (if required) | Author's Initials |
| 1                                                                                                                                                               | Page 1, section 1.3, last sentence<br>Change to "it has several easily recognizable peaks."                       | N                |                                                                                                                                                                                                                                                          |                                 |                   |
| 2                                                                                                                                                               | Page 5, section 6.1.2.1, first sentence<br>"Misaligned" is not defined. Add "see section 8.1" after "misaligned". | N                |                                                                                                                                                                                                                                                          |                                 |                   |
| 3                                                                                                                                                               | Page 10, section 9.1.6<br>Change the section number from 9.1.1.6 to 9.1.6                                         | Y                |                                                                                                                                                                                                                                                          |                                 |                   |
|                                                                                                                                                                 |                                                                                                                   |                  |                                                                                                                                                                                                                                                          |                                 |                   |

GPO 16% (Test)  
(1/92)

Figure 3. Example of a Record of Review





## Environmental Procedures Catalog Document Addition/Revision

**Procedure Title:** Standard Practice for Quality Assurance, GA-3(P), Rev 0, 12/98

**Requester:** Farlie Pearl, QA Coordinator

**Justification:** The applicable Quality Assurance (QA) requirements are incorporated or referenced within the text of the *Monticello Mill Tailings Site Operable Unit III Interim Remedial Action Surface Water and Ground Water Monitoring Program* (MAC-MSGRAP 1.3.5-2, Rev. 1, April 1999) to meet project needs and apply QA requirements in a graded manner as prescribed by the *Monticello Projects Quality Assurance Program Plan* (MAC-MRAP 1.3.10, Rev. 9, July 1998), and as directed in DOE Order 5700.6C.

**Proposed Change:** The "Standard Practice for Quality Assurance", procedure GA-3(P) from the Environmental Procedures Catalog (manual GJO 6) is applicable as the QA program for the *Monticello Mill Tailings Site Operable Unit III Interim Remedial Action Surface Water and Ground Water Monitoring Program*. See Attachment 1, which lists each program element and adapts the requirements to the needs of the project by noting "no change", "modification", or "clarification" as applicable to the element.

---

### Authorization for Changes to Catalog Procedures

☐ New Document

☐ Change to Existing Procedure

☐ Adopt Procedure

Procedure Number Assigned \_\_\_\_\_

Procedure Title \_\_\_\_\_

Approval for Inclusion in Environmental Procedures Catalog:

\_\_\_\_\_  
Environmental Procedure Advisory Committee Chair

\_\_\_\_\_  
Date

---

### Authorization for Project Specific Modifications to Existing Catalog Procedures

Project Specific Change for MMTS Operable Unit III Interim Remedial Action Surface Water and Ground Water Monitoring Program (MAC-MSGRAP 1.3.5-2)

Effective Date April 5, 1999

Reviewed By Donna R. Riddell  
Technical Author or  
Proficient Designee

3/31/99  
Date

Approved By Mike McCillen  
Manager or Designee

4/1/99  
Date

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## ***Environmental Procedures Catalog***

### **Document Addition/Revision**

Procedure Title: Standard Practice for Quality Assurance, GA-3(P), Rev. 0, 12/98

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The following clarifications are made to the QA program implemented through the *MMTS Operable Unit III Interim Remedial Action Surface Water and Ground Water Monitoring Program*:

- 6.1 **QA Program - Clarification:** The Quality Assurance Program will be implemented through the requirements established and documented in the Operable Unit III Interim Remedial Action Surface Water and Ground Water Monitoring Program (MAC-MSGRAP 1.3.5-2) and the procedures attached to or referenced in the plan. (reference Criterion 1)
- 6.2 **QA Coordinator Responsibilities - Clarification:** A separate QA Plan is not required for this work. The Standard-Level QA requirements are incorporated in the Operable Unit III Interim Remedial Action Surface Water and Ground Water Monitoring Program and by the use of procedure GA-3(P), and relevant Criteria or Instructions in the GJO QA Standards (manual GJO 1). (reference Criterion 1 and QAIs 1.4 and 1.7)
- 6.3 **Planning - No change** (reference Criterion 1 and QAIs 1.5 and 6.3)
- 6.4 **Readiness Reviews - Clarification:** A documented Activity Review or WWR is not required for this scope of work. Field personnel are responsible for assuring that procedures, equipment, supplies, and logistics for conducting the sampling are adequate and ready for the job. The field "Lead" is responsible for assuring project documents are available at the work locations and that training requirements for team members have been verified. (reference Criterion 1 and QAIs 1.5 and 1.8)
- 6.5 **Training - Clarification:** Proficiency qualifications apply to the "Lead" field personnel responsible for independently implementing EPC procedures and/or directing the activities of other team members through this field sampling plan. Proficiency requirements are specified in Section 8 of the GJO Training Manual (manual GJO 4). Project Health and Safety (H&S) training requirements will be maintained as specified by the Monticello Projects H&S Plan (MAC-MRAP 1.3.4). (reference Criterion 2)
- 6.6 **Procurement Control - Clarification:** These requirements apply to the purchase of sample containers. The DOE-GJO Analytical Laboratory will perform analytical services. If analytical services are subcontracted, QA personnel will review the procurement documents. (reference Criterion 7 and QAI 7.3)
- 6.7 **Procedure Requirements - Clarification:** The Program Directive Procedure, Chapter 9 in the Monticello Desk Procedures Manual (manual MAC-3005) will be used to make interim changes to the plan. Program Directives will be incorporated into subsequent revisions to the plan as appropriate. Section 8.2 of procedure GA-1(P) is applicable for modifying EPC procedures to meet project requirements during planning. Field deviations from requirements specified in the plan or procedures will be thoroughly documented as a Field Variance and the information will be used during data review and evaluation and, as appropriate, for nonconformance reporting. (reference Criterion 5)
- 6.8 **Calibration Control - No change** (reference Criterion 8 and QAI 8.2)
- 6.9 **Field Documentation - No change** (reference Criterion 5)
- 6.10 **Sample Identification and Control - No change** (reference Criterion 5)
- 6.11 **QA Objective for Measurement Data - No change** (reference QAIs 1.7 and 6.3)
- 6.12 **Document Reviews - Clarification:** As a minimum, independent reviews of logbook and data sheet entries will be performed and documented at the conclusion of the sampling event. (reference Criterion 5)
- 6.13 **Nonconformance Control - No change** (reference QAI 3.4)
- 6.14 **Corrective Action - No change** (reference Criterion 1 and QAIs 1.3 and 3.5)
- 15 **Independent Assessments - Clarification:** Independent assessments may be performed internally through surveillance, field visits, or document reviews. External Audit or Assessment may be conducted by the regulators. Findings resulting from independent assessments (both internal or external) will be responded to in a timely manner and corrective actions will be administered, tracked, and verified complete in accordance with the requirements of Criterion 10 in the GJO QA Standards (manual GJO 1). (reference Criterion 10 and QAIs 10.2 and 10.3)

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# Standard Practice for Quality Assurance

## 1. Scope

1.1 This practice applies to all activities that will be conducted in accordance with the procedures in this catalog. The *GJO Quality Assurance Standards* (GJO 1) is the basis for this standard practice. Project leads should notify the QA manager of new projects or activities to ensure adequate evolution of quality issues. When a program-specific Quality Assurance Program Plan (QAPP) exists, the Work Plan will prescribe implementation of the site-specific requirements of the QAPP. Responsibility for the quality of work rests with those performing the work. Quality Assurance (QA) Groups support programs and projects by the assistance of a QA Coordinator and through monitoring and surveillance activities.

## 2. Hazard Analysis

2.1 No hazards requiring controls have been identified for this practice. Site-specific controls are specified in the Health and Safety Plan for a particular project.

## 3. Referenced Documents

3.1 Title 10, *U.S. Code of Federal Regulations*, Part 830, Section 120 (10 CFR 830.120), "Quality Assurance Requirements"

3.2 *GJO Training Manual* (GJO 4) Section 8.0 "Environmental Qualification Procedures"

3.3 *GJO Environmental Procedures Catalog* (GJO 6)

Procedure GA-1(P), "Standard Practice for Preparing or Revising Procedures for the *GJO Environmental Procedures Catalog*"

Procedure GA-2(P), "Technical Comments on ASTM D 5283-92—Standard Practice for Generation of Environmental Data Related to Waste Management Activities: Quality Assurance and Quality Control Planning and Implementation"

Procedure GT-1(P), "Standard Practice for Field Documentation Processes"

Procedure GT-2(P), "Standard Practice

for Sample Labeling"

Procedure GT-3(P), "Standard Practice for Chain-of-Sample-Custody Control and Physical Security of Samples"

3.4 Contractor's Procurement Manual

3.5 *GJO Quality Assurance Standards* (GJO 1)

Criterion 1, "Quality Assurance Program"

Quality Assurance Instruction (QAI)  
1.3, "Suspension of Activities"

Criterion 3, "Quality Improvement"

QAI 3.4, "Nonconformance  
Reporting, Disposition, and Closure"

QAI 3.5, "Corrective Action Request  
System"

Criterion 8, "Inspection and Acceptance  
Testing"

QAI 8.2, "Calibration System"

## 4. Terminology

4.1 *Assessment*—An independent planned and documented assessment performed to determine by investigation, examination, or evaluation of objective evidence the adequacy of and compliance with established instructions, procedures, drawings, or other applicable documents, and the effectiveness of implementation of requirements.

4.2 *Calibration*—Comparison of measurement equipment with reference standards of greater accuracy to detect, quantify, report, and eliminate inaccuracies. Calibration may include adjustment or alignment, depending on the as-found condition of the equipment.

4.3 *Controls*—Documented administrative rules, orders, instructions, procedures, policies, practices, and designations of authority and responsibility.

**4.4 Corrective action**—Measures taken to reduce or eliminate conditions adverse to quality and, where necessary, to prevent recurrence.

**4.5 Corrective Action Request (CAR)**—A document used to identify significant conditions adverse to quality, identify corrective action, and record verification of corrective action taken.

**4.6 Deviation**—A departure from specified requirements or procedures.

**4.7 Document**—Any written or pictorial information describing, defining, specifying, reporting, or certifying activities, requirements, procedures, or results. A document is not considered to be a record until it includes actual data, results, or information and is authenticated.

**4.8 Documentation**—A body or group of documents; or the process of generating documents or assembling of a group of documents.

**4.9 Document control**—The act of assuring that documents are reviewed for adequacy, approved by authorized personnel for release, and distributed to and used at locations where the activity is performed. Document control includes assuring changes to the documents receive the same controls as the originals.

**4.10 Indoctrination and Training**—All of the actions necessary to assure that personnel are properly trained to manage or perform activities that affect quality, such as classroom sessions, on-the-job training, or required reading. Employees must be familiar with and understand the purpose, scope, and implementation of the QA Program as it applies to their work.

**4.11 Interface**—Interaction among individuals, groups, or organizations.

**4.12 Measurement and Test Equipment (M&TE)**—Devices or systems used for calibrating, measuring, gauging, testing, or inspecting to control, to acquire data, or to verify conformance to specified requirements. M&TE includes devices or systems used to acquire research, development, or test data or to determine compliance with design, specifications, or other technical requirements. Systems used for measurement or testing include components from the sensing element through the output or recording device.

**4.13 Nonconformance**—A deficiency in a

characteristic, procedure, or documentation that renders the quality of an item unacceptable or indeterminate. Examples of nonconformances include, but are not limited to, physical defects; test failures; incorrect or inadequate documentation; and deviations from prescribed processing, inspection, test procedures or other documented technical requirements.

**4.14 Nonconformance Report (NCR)**—The document used to report the identification and disposition of nonconformances.

**4.15 Planning document**—A document that specifies the work to be completed, sampling strategies, tests required, level of quality control (QC) applied, personnel assignment and responsibilities, and deliverables. Some projects may require Field Sampling and Analysis Plans or other specified planning documents.

**4.16 Procedure**—A document that systematically specifies or describes the way an activity is to be performed. As used in this catalog, a procedure may be a test method, practice, or guide.

**4.17 Procurement document**—Purchase requisitions, purchase orders, drawings, subcontracts, specifications, and instructions formally approved and used to perform the procurement process. These documents define the requirements that must be met before items or services may be accepted.

**4.18 Program plan**—A written description of the activities required for achieving the goals or objectives of a program. The plan describes the strategy to be followed and the major actions to taken to achieve those objectives. The plan addresses program-related elements, including program interfaces, schedule, major milestones, budget, technical control, quality assurance, and program control.

**4.19 Quality Assurance**—All planned and systematic actions necessary to provide adequate confidence that a facility, structure, system, or component will perform satisfactorily in service.

**4.20 Quality Assurance Coordinator**—A member of the QA staff assigned to provide QA assistance to the management of activities and programs in quality assurance matters. The QA Coordinator assists in establishing the QA

Program Plan and evaluating compliance with the Plan.

**4.21 Quality Assurance Program**—The system of activities associated with defining, implementing, and verifying compliance with the requirements for QA. The QA Program is described in the *GJO Quality Assurance Standards* (GJO 1).

**4.22 Quality Assurance Officer**—The Manager of the contractor organization to which QA staff are assigned. The Manager is independent of Program/Project assignment.

**4.23 Quality Assurance Program Plan**—A document identifying the requirements that the Program or Activity manager and the QA Coordinator have judiciously selected from the overall QA Program, along with customer's QA requirements that are to be imposed on a particular program.

**4.24 Quality Control**—Those quality activities necessary to control and verify the features and characteristics of an item, material, process, facility, or service to specified requirements.

**4.25 Record (Quality Assurance)**—A document that furnishes evidence of the quality of items or activities and that has been verified and authenticated as technically complete and correct. Records may include photographs, drawings, magnetic tape, and other data-recording media.

**4.26 Sampling and Analysis Plan**—A plan that defines sampling strategies, data-quality objectives, traceability, QC, and records requirements.

**4.27 Shall**—Denotes a mandatory requirement or action. "Must" and "will" are synonymous with "shall" and "will".

**4.28 Signature (or signed)**—A person's name, written by that person, including given names or initials and full last name.

**4.29 Stop Work**—To discontinue all or any of the activities related to the fulfillment of contract obligations.

**4.30 Stop Work Order**—A formal request by an oversight organization member to suspend activities when other measures to obtain corrective action have failed, and risk resulting

from loss, damage, or continued noncompliance is high (Reference 3.5).

**4.31 Surveillance**—The act of monitoring or observing to determine whether an item or activity conforms to specified requirements.

**4.32 Technical review**—A formally documented review of technical material performed by individuals independent of those directly responsible for the work but who may be members of the organization that performed the work.

**4.33 Traceability**—The capacity for tracing the history, application, or location of an item or sample by means of documentation or physical identification.

**4.34 Variance**—A deviation from "must," "shall," or "will" statements in a procedure.

## 5. Significance and Use

**5.1** The GJO Quality Assurance Program is defined by the *GJO Quality Assurance Standards* (GJO 1), which is based on DOE Order 5700.6C "Quality Assurance". The *GJO Quality Assurance Standards* (GJO 1) specifies QA requirements which are graded into "Standard" and "Q" level requirements. The *GJO Environmental Procedures Catalog* (GJO 6) implements the "Standard" level requirements unless the planning document or the procedure specifies "Q" level requirements.

**5.2** This practice defines the QA Program elements that are routine to the use of test methods, guides, and practices. This practice should be used along with the planning documents that may specify additional program-specific requirements.

## 6. Procedure

**6.1** The Quality Assurance Program will be implemented through the *GJO Quality Assurance Standards* (GJO 1), QAPPs, planning documents, and the instructions in this catalog.

**6.2** QA Coordinators are assigned to support program or project activities. The QA Coordinator will assist the Program or Project Manager in evaluating the need for and preparing a QAPP to grade the level of quality needed for the program. The QA Coordinator will also



review planning documents to verify that any QA requirements for the program are included.

6.3 The planning document will describe and plan field activities, as described in Procedure GA-2(P), "Technical Comments on ASTM D 5283.92—Standard Practice for Generation of Environmental Data Related to Waste Management Activities: Quality Assurance and Quality Control Planning and Implementation." The preparer of the planning document needs to use the applicable program QAPP requirements as an input to the Work Plan.

6.3.1 The planning document will designate the organization(s) responsible for performing particular tasks and the interfaces between work teams, support organizations, and program personnel; and will specify responsibilities and authorities of team members. The planning document will specify how the quality of work will be determined and by whom.

6.4 GJO QA Standards, QAI 1.8, "Work Readiness Reviews", provides instructions for performing work readiness reviews.

6.5 Personnel performing work will be trained as defined in the *GJO Training Manual* (GJO 4). Only trained personnel will be assigned to conduct work using the *GJO Environmental Procedures Catalog* (GJO 6). A trained person can supervise the assistance of personnel who have not received training on a particular procedure. The trained person will record any data and will be responsible for the results of the activity. The Project Manager or designee will verify personnel qualifications and training prior to work assignment.

6.6 The purchase of items or services will be accomplished as specified in the contractor's procurement manual. As appropriate, procurement documents will specify the scope of work, technical requirements (reference to existing codes or standards is recommended where possible), rights of access, and documents to be submitted.

6.6.1 QA review of procurement documents may be considered when the items to be purchased must meet quality requirements or other standards. Examples of procurements where QA review is beneficial are subcontracted services, instrument calibration, and equipment fabrication.

6.7 Work will be controlled by instructions, procedures, and drawings. Procedures will be

prepared, reviewed, approved, and issued prior to beginning the work. The procedures will be controlled to ensure that personnel have current and correct copies of the procedures, instructions, and drawings. Procedure GA-1(P), "Standard Practice for Preparing or Revising Procedures from the *GJO Environmental Procedures Catalog*" will be used for procedures in this catalog.

6.7.1 Should modification to a procedure be needed for a particular task, the revised procedure must be documented as described in Procedure GA-1(P), "Standard Practice for Preparing or Revising Procedures for the *GJO Environmental Procedures Catalog*."

6.7.2 Variations from procedures in the field will be documented on the data sheet or field notebook. The variation will be evaluated for its effect during data review.

6.8 The *GJO QA Standards* (GJO 1) QAI 8.2 "Calibration System" applies to any activity that requires calibrated M&TE. Facility Management will provide assistance in securing maintenance and calibration services upon request.

6.8.1 Personnel using instruments that affect or evaluate the quality of an activity are responsible for ensuring that the instrument is controlled and that accuracy is documented. The instruments must have a label that documents the calibration status. If labeling is not feasible, the records must show current calibration.

6.8.2 Instruments will be checked for proper functioning daily before use. The documentation must show that the instrument is functioning within the established parameters. Verification of a current calibration sticker will be performed during the operational check.

6.9 All project work activities will be documented in permanent form. Records must be legible, identifiable, reproducible, signed, and dated. Records will be protected from loss or damage by reasonable handling of documents. Corrections will be made by crossing through the entry with a single line, entering the correction, initialing, and dating. Refer to Procedure GT-1(P), "Standard Practice for Field Documentation Processes" for record preparation, protection, and disposition.



6.10 Sample traceability will be maintained through use of Procedure GT-2(P), "Standard Practice for Sample Labeling" and Procedure GT-3(P), "Standard Practice for Chain-of-Sample-Custody Control and Physical Security of Samples."

6.11 The planning document will specify QA objectives for measurement data, if applicable (such as accuracy, precision, completeness, representativeness, and comparability). The plan will detail how the objectives will be satisfied.

6.12 The following types of document reviews will be conducted:

6.12.1 The individual performing the test or practice will review the data to verify correctness. When data are collected electronically, the individual will review the printed representation.

6.12.2 A person other than the person recording the data will review individual data sheets or records for reasonableness and completeness. The reviewer will document the review on the data sheet by a legible signature and date.

6.12.3 Formal and informal reports will be reviewed as described in the contractor's administrative policies and procedures.

6.12.4 Reviews of procedures in the *GJO Environmental Procedures Catalog* (GJO 6) will be conducted as described in Procedure GA-1(P), "Standard Practice for Preparing or Revising Procedures for the *GJO Environmental Procedures Catalog*." Contractor procedure reviews will be conducted and documented as prescribed by the contractor's administrative policies and procedures.

6.12.5 Procurement documents will be reviewed for inclusion of technical requirements, deliverables, scope of work, quality requirements, and rights of access (when appropriate).

6.12.6 Data-quality reviews will assess whether the data quality objectives, as a whole, have been achieved.

6.13 Items or activities that do not conform to written requirements will be identified, controlled, and corrected. Nonconformances are deficiencies in characteristic, procedure, or documentation that render the quality of an item unacceptable or indeterminate. Nonconforming items or data that have been transmitted to other organizations must be reported and evaluated as

directed in QAI 3.4 of the *GJO Quality Assurance Standards* (GJO 1). The person who identifies a nonconformance will initiate a report using the Nonconformance Report (Form 1594). The QA Coordinator will be notified of and assist in the administration of the Nonconformance Report.

6.14 All work will be conducted in accordance with appropriate quality standards. Those with the responsibility for the work have primary responsibility for achieving quality and taking corrective actions as needed to maintain the quality of work.

6.14.1 When conditions adverse to quality have been identified through Nonconformance Reports, audits, or surveillance and corrective action has been ineffective, the contractor's QA Officer may issue a CAR as directed in QAI 3.5 of the *GJO Quality Assurance Standards* (GJO 1). Managers of organizations receiving a CAR are responsible for evaluating the condition, proposing corrective actions, and completing corrective actions in a timely manner. The QA Officer will evaluate proposed corrective action or recovery by the responsible organization and close the CAR as appropriate. At the direction of the QA Officer, the QA Coordinator will verify implementation of the corrective action.

6.14.2 When significantly adverse conditions have been identified and management response has not been initiated or is ineffective, suspension of activities may be initiated by the contractor's QA Officer through a Stop Work Order as directed in QAI 1.3 of the *GJO Quality Assurance Manual* (GJO 1). The QA Officer will evaluate proposed corrective action or recovery by the responsible organization and lift the Stop Work Order as appropriate. At the direction of the QA Officer, the QA Coordinator will verify implementation of the corrective action.

6.15 The contractor's QA Group will verify implementation of the QA Program by conducting assessments and surveillance of programs and activities of contractor organizations. Qualified personnel will conduct audit activities using the requirements in the *GJO Quality Assurance Standards* (GJO 1) and internal QA procedures.

## **7.0 Keywords**

7.1 See Section 4., "Terminology."



# Standard Practice for Field Documentation Processes

## 1. Scope

1.1 This standard practice covers reproducibility, legibility, accuracy, completeness, protection, identification, and error correction of records. The practice describes the control, data entry, content, review, and storage of field documents such as logbooks, field notebooks, data sheets, and other records.

## 2. Hazard Analysis

2.1 No hazards requiring controls have been identified. Site-specific controls are available in the Health and Safety Plan for a particular project.

## 3. Referenced Documents

3.1 *MACTEC-ERS General Administrative Procedures Manual (MAC-1000)*, Section 3, "Records Management Procedure"

3.2 *GJO Quality Assurance Standards (GJO 1)* Criterion 4, "Documents and Records".

3.3 *WASTREN-Grand Junction Management Policy Manual*

3.4 U.S. Environmental Protection Agency, *Test Methods for Evaluating Solid Waste, Vol. II, Field Manual, Physical/Chemical Methods*, SW-846, Office of Solid Waste and Emergency Response, November 1986, 3rd Edition.

## 4. Terminology

4.1 Records—Information or data on a specific subject collected and preserved in writing or other permanent form that has been verified and authenticated as technically complete and correct. Records may but are not limited to include data sheets, logbooks, field notebooks, maps, drawings, photographs, and electronic data-recording media.

4.2 *Technical record books*—For purposes of this practice, technical record books will refer to logbooks and field notebooks. These books are to be bound and the pages consecutively numbered.

## 5. Significance and Use

5.1 This practice will be used to document results of tasks performed using the *GJO Environmental Procedures Catalog (GJO6)*, unless the project Work Plan provides an alternate practice.

5.2 This practice includes the use of technical record books for direct data entry or as journals referring to the location of associated supporting documents for activities.

5.3 Documentation of the results produced from performing tasks is necessary to provide adequate evidence of compliance with requirements, provide an adequate basis for design decisions, and document techniques and conditions of sample collection.

## 6. General Procedures for Records

6.1 All records produced from work performed according to procedures in the *GJO Environmental Procedures Catalog (GJO 6)* must meet the following requirements:

6.1.1 Records must clearly describe the work performed. Enough detail must be provided to enable someone of equivalent skill and experience in the technology to repeat the work as originally performed.

6.1.2 Records must be clear, legible, and reproducible. Black ink is preferred. Reproducible photocopies of penciled documents are acceptable as records.

6.1.3 Errors will be corrected by lining through the incorrect entry with a single line, making the correction, and initialing and dating the correction. The erroneous information must not be obliterated or erased.

6.1.4 Records must specify the activity conducted, the program sponsor, and the method used, if applicable. The signature of the person who performed the work and the date it was performed must appear on each page of a record and on any attached sheets. (Initials are acceptable if an initials log identifies the person.)

6.1.5 For short-term tasks, the Work Plan will define the records to be maintained for each task conducted and the disposition of the records. The following are suggested records of a short-term task:

6.1.5.1 Operational check data.

6.1.5.2 Data sheets.

6.1.5.3 Technical record books.

6.1.5.4 Official correspondence.

6.1.5.5 Planning documents.

6.1.5.6 Electronically or magnetically stored data.

6.1.6 For ongoing programs, a Working Records File Index defines what records will be generated, how long they will be retained, and the disposition of the records (see References 3.1 and 3.3).

6.1.7 Records must be protected against damage, deterioration, and loss while in the field, during data review, and until they are submitted to a storage facility. Records must be isolated from any source of contamination.

6.1.8 An independent reviewer will review data sheets or data contained in technical record books, as well as electronic data collection and data entry, as described in Section 7.5.

6.1.9 All data will be reviewed before personnel leave a remote site. The review will ensure that no additional sampling or data acquisition is required before departure.

6.1.10 When the procedure specifies compilation of data sheets, the data must be legible and traceable to the activity, project, and method used. The person completing the data sheet will sign and date the sheet and ensure that applicable spaces are completed.

## **7. Procedures for Technical Record Books**

7.1 Technical record books will be bound books with sequentially numbered pages. Each book will be given a unique identifier.

**7.2 Issue and Control of Technical Record Books**—A technical record book will be assigned to an activity or a person for use on a project. The technical record book will be transmitted to the Project Manager or designee upon completion. If a technical record book contains information on more than one activity or project, the technical record book will clearly identify the portion associated with each activity or project. Reproducible copies of applicable sections of these books may be submitted to the Project Manager or designee as records.

7.2.1 The Project Manager shall determine the following and make a written record of the decisions:

7.2.1.1 Who will issue technical record books.

7.2.1.2 The number of each technical record book and the person to whom the book is issued.

7.2.1.3 The expected location for each technical record book when not in use (building and room number).

7.2.1.4 The reviewer of each technical record book and the frequency of reviews.

7.2.1.5 Whether support organizations are to use technical record books dedicated to the project or whether they will be required to furnish copies of applicable pages from technical record books supporting several projects.

7.2.2 The person to whom a technical record book is issued shall take the following steps upon receipt of a new technical record book:

7.2.2.1 Review general information on maintenance of the technical record book.

7.2.2.2 Complete the information block (if any) on the first sheet inside the front cover.

7.2.2.3 Identify the technical record book by entering the project number and title and the applicable task or subtask numbers as appropriate.

7.2.2.4 Determine whether to reserve specific pages for a Table of Contents and for the names of people who make entries and who will review the technical record book.

7.2.2.5 The first entry in the book shall describe the work covered and, as appropriate, the name of the sponsor, the Work Order or Statement of Work number, and the objectives of the work.

7.2.2.6 Prepare and maintain a list of the printed name, written signature, and initials used by each person who is authorized to make entries, including review entries.

### 7.3 Rules for Data Entry

7.3.1 Pages shall be kept intact. No page is to be left completely blank or removed from the book.

7.3.2 Use pages consecutively. If a page has entries from more than 1 day, each entry shall be signed and dated. If a page or part of a page must be left blank, it must be ruled across, signed, and dated. If entries for a given subject are made on two or more pages that are not consecutive, each page must be cross referenced to the previous and following entries.

7.3.3 Record all data as required by procedures for the activity being performed. Enter all data directly in a technical record book when practical. If loose sheets, such as test data sheets, photocopies, or photographs must be added to a technical record book, proceed as follows:

7.3.3.1 Glue, tape, or staple each sheet or part of a sheet to the next blank page or blank space, according to the amount of space needed.

7.3.3.2 Enter on the page of the technical record book a description of the material that is attached, and enter on each attachment the technical record book number and page number. This information will allow identification of the attachment if it comes loose.

7.3.4 Describe or reference in the technical record book any other permanent written or visual records generated for the project and not readily available in the open literature or that cannot be directly inserted because of size or bulk (e.g., data sheets, computer printouts, films, or magnetic media). Any project records that are cited must be filed and controlled as records. Records that are readily available in the open literature need only be referenced. The purpose is to provide a clear, complete record of activities and supporting documents.

7.3.5 The last entry in a technical record book shall be either a statement that the work was concluded or a reference to a sequential technical record book.

7.4 *Content of Technical Record Books*—The following information may be entered in technical record books, as applicable:

7.4.1 Table of Contents, consisting of pages with continuing entries.

7.4.2 What work was done and how it was done, including such information as a description of the facility, test design, measuring and test equipment (by serial number), and a reference by number and title to any standard procedure used.

7.4.3 Instrument numbers or equipment used, if not specified in a referenced procedure.

7.4.4 Field checks or calibrations that are not documented elsewhere.

7.4.5 Identification of personnel and responsibilities or duties of each person.

7.4.6 Why the work was done, including any Statement of Work under which the work was done and with what objective.

7.4.7 What results were obtained. Observations made, the review of the results, and nonconformances and deficiency reports may be included.

7.4.8 Temperature, weather, humidity, wind speed and direction, or other environmental influences that might affect the results.

7.4.9 Documentation of variances from planned activities. A variance is considered to be a deviation from "shall", "must", or "will" statements of a procedure.

7.4.10 Location of the activity, including site and sample or test location.

7.4.11 Name and address of field contact.

7.4.12 Sampling entries:

7.4.12.1 Purpose of sampling.

7.4.12.2 Description of sampling point and sampling methodology.

7.4.12.3 Number of samples taken and volume.

7.4.12.4 Date and time of sample collection.

7.4.12.5 Sample destination (name of laboratory) and how transported (hand carried or name of carrier, such as United Parcel Service or Federal Express).

7.4.12.6 References such as maps or photographs of the sampling site.

7.4.13 Entries relating to waste:

7.4.13.1 Producer of waste and address, if different for that location.

7.4.13.2 Type of process (if known) that produced the waste.

7.4.13.3 Type of waste (e.g., sludge, wastewater).

7.4.13.4 Suspected composition and concentrations of waste.

7.4.14 Other appropriate entries such as calculations, problems encountered and actions taken to resolve them, or interfaces with agencies.

7.5 *Review of Technical Record Books*—An independent reviewer will review technical record books for content, accuracy, legibility, calculations, error correction, and reproducibility (see Reference 3.2).

7.5.1 A reviewer will review electronic data collection or data entry for correctness and accuracy by comparison of originals with printed data or by review of the graphic representation of the data.

7.5.2 The reviewer will check for completeness, validity of data, and traceability between each page and the items or activities to which it applies. The reviewer will take action to correct any deficiencies.

7.5.3 When the reviewer is satisfied that the recorded information is complete and correct, the reviewer will sign and date the technical record

book and indicate the pages and supporting documents that were reviewed.

7.5.4 Written comments by a reviewer that are clearly identified as review comments will not require review by a second reviewer.

7.6 *Storage of Technical Record Books*—Technical record books shall be stored in fire-resistant metal file cabinets or otherwise protected from damage when not directly in use. Records shall not be left unprotected overnight or on holidays, vacations, or weekends (see Reference 3.2).

## 8. Keywords

8.1 Data sheets, documentation, field documentation, field notebooks, logbooks, records, and technical records books.

# Standard Practice for Sample Labeling

## 1. Scope

1.1 This procedure addresses labeling requirements and recommended practices for labeling samples that are collected in the field and intended for analysis at a later time. The materials sampled may include, but are not limited to, solids such as soils and cores, liquids and sludges, and gases.

1.1.1 This procedure does not address labeling practices for any in situ measurements.

1.2 This procedure is intended for use with a variety of sample types, including grab samples, composite samples, duplicate samples, and split samples.

1.3 All samples collected by Contractor personnel shall have a sample label and a Contractor-generated sample number.

## 2. Hazard Analysis

2.1 No hazards requiring controls have been identified. Site-specific controls are available in the Health and Safety Plan for a particular project.

## 3. Referenced Documents

3.1 GJO *Environmental Procedures Catalog* (GJO 6)

GT-1(P), "Standard Practice for Field Documentation Processes"

GT-3(P), "Standard Practice for Chain-of-Sample-Custody Control and Physical Security of Samples"

## 4. Terminology

4.1 *Chain-of-Sample-Custody Form*—A form used to document sample custody and receipt. It also may contain other information, such as the sample analyses required and traceability.

4.2 *Field*—Any place where the material for analyses or testing is collected.

4.3 *Duplicate samples*—More than one sample collected from the same source location, but placed in separate containers. Also called multiple samples.

4.4 *In situ*—In place; not removed from the point of original deposition.

4.5 *Sample (n)*—A portion of material collected from a larger mass that represents the characteristics of that mass.

4.6 *Sample (v)*—To select and collect a sample.

4.7 *Sample label*—The documentation attached to the sample or sample container and marked with required information about the sample. An example is shown in Figure 1.

|                                                                                             |                |
|---------------------------------------------------------------------------------------------|----------------|
| <b>Grand Junction Office</b><br>2597 B 3/4 Road<br>Grand Junction, CO 81503<br>970/248-6000 |                |
| Sample No. _____                                                                            | Date _____     |
| Sampler _____                                                                               | Time _____     |
| Project Site _____                                                                          | Location _____ |
| Sample Type _____                                                                           |                |
| Comments _____                                                                              |                |
| _____                                                                                       |                |

Figure 1. Example of Sample Label

4.8 *Sample log*—A document that lists all samples collected during a field visit or visits. A Chain-of-Sample-Custody form or sample ticket book are examples of sample logs.

4.9 *Sample number*—The unique identification number assigned by the Contractor to each sample and attached to, or written on, the sample label or sample container. The sample number will normally consist of three alpha and three numeric characters and will have both eye-readable and bar-code portions (Figure 2).

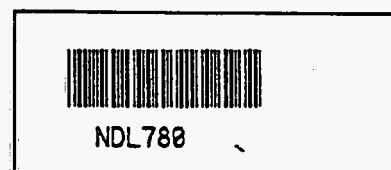


Figure 2. Example of a Sample Number



4.10 *Sample Plant*—the facility at the Grand Junction Office where samples are prepared for analysis.

4.11 *Sample ticket book*—A soft-bound book consisting of 25 sample numbers, one number per page. Each page is backed by two duplicating no-carbon required (NCR) sheets. For each sample number, a separate page containing 27 duplicate numbers is included. The duplicate number labels are self-adhesive.

4.12 *Split sample*—A sample that has been subdivided into two or more parts, each representative of the original sample.

## 5. Significance and Use

5.1 All Contractor personnel shall use this procedure for sample identification unless an approved alternate procedure is included or referenced in the official project records. Alternate procedures shall include the minimum information identified in Section 8.4.

## 6. Materials

6.1 Preprinted Contractor sample labels with adhesive backing.

6.2 Preprinted sample numbers with adhesive backing or a sample ticket book (GJPO 1854) with preprinted adhesive-backed sample numbers.

6.3 Ballpoint pen with reproducible, water-proof ink.

6.4 Clear plastic tape (normally 2 inches wide).

6.5 Sample log.

## 7. Procedure for Obtaining Contractor Sample Numbers

7.1 Bar-coded sample numbers are printed by the Wastren Information Management Services group. To avoid duplication of numbers, the computer software that produces the numbers will prompt the user with the starting number for the new series to be printed.

7.2 The sample numbers are printed on a roll to be attached to sample labels to be bound into the sample ticket books.

7.3 Sample numbers and labels are obtained from the Field Services administrative staff. If appropriate, obtain sample ticket books from the Contractor's Sample Plant.

7.4 The issuing organization will maintain a log of the sample numbers or ticket books issued, the requester's name, and the date of issue.

7.5 The issuing organization shall obtain a new stock of sample numbers as needed from Wastren's Information Management group.

## 8. Procedure for Using Sample Labels

8.1 Complete the sample label before or after attachment to the sample container. If labels are not available, write the required information directly onto the sample or sample container. Never write directly on a sample that is to be chemically analyzed.

8.2 Use waterproof, reproducible ink to complete the required label information.

8.3 Normally, the sampler will complete the entire label. If some of the requested information is not relevant, write "NA" for "not applicable" in that space.

8.4 The minimum information required on the sample label shall include

8.4.1 *Sample number*.

8.4.2 *Date*—The date the sample was collected.

8.4.3 *Sampler identification*—The name or initials of the person who collected the sample.

8.4.4 *Project site*—The area or property defined in project documents containing one or more sample locations. The property may be identified by a number.

8.4.5 *Sample location*—The location at which the sample was collected. Examples of sample locations include well numbers, grid locations, or surveyed coordinates.

8.5 Additional information that may be appropriate on the label includes

8.5.1 *Time*—The time at which the sample was collected.

**8.5.2 Sample type (matrix)**—One or more terms that describe the type of sample. This description may cover sample material such as soil, water, sludge, air, or core. It may also include the type of sample, such as composite, grab, or wipe.

**8.6** Attach the preprinted sample number to the sample label. If the preprinted number is illegible or does not adhere to the label, the sampler may write the sample number on the sample, sample label, or sample container. The sampler also may write the number on tape and attach it to the sample.

**8.7** Maintain a record of sample numbers and other pertinent information on a sample log. See Procedure GT-1(P), "Standard Practice for Field Documentation Processes" and Procedure GT-3(P), "Standard Practice for Chain-of-Sample-Custody Control and Physical Security of Samples," reference 3.1.

**8.8** When needed, protect the completed sample labels from moisture and abrasion by placing a piece of clear plastic tape over the label.

## **9. Procedure for Using Sample Ticket Books**

**9.1** Sample ticket books contain preprinted numbers for labeling multiple sample fractions (e.g., water samples from one well) or split samples. A copy of a page from a sample ticket book (GJPO 1854) is shown in Figure 3.

**9.2** If multiple sample fractions or duplicate samples are taken at the same location or if split samples are made in the field, the sampler shall identify each sample by removing an adhesive-backed sample number from the book and attaching it to the sample label or container. The sample number shall be identical for each sample in the entire group of duplicates or splits.

**9.3** Duplicate samples or split samples each may be assigned a unique sample number for purposes of documenting the precision of the sampling and analysis process. These samples are commonly referred to as "blind duplicates" or "field duplicates."

**9.4** The information required on the sample ticket is summarized on the inside flap cover of the ticket book, as shown in Figure 4.

When completing the ticket, the cardboard cover should be inserted after the pink page of the current ticket to prevent copying information onto the next ticket. A ballpoint pen should be used with sufficient pressure to ensure duplication onto all copies of the NCR sheets.

**9.5** Normally, the white copy of the ticket is retained by the project manager, the canary copy is forwarded to the Sample Plant or analytical laboratory with the samples, and the pink copy remains in the ticket book. This distribution may vary depending upon the needs of the project.

## **10. Keywords**

**10.1** Label, sample, sample labeling, sample log, sample number, and ticket book.

NDG 851

Project UGW

Site Tuba City Location 945

Date 7-16-98 Time 1445 Matrix water

Interval NA Sampler Sellers/Kempel

Comments \_\_\_\_\_

| Analyte(s)                      | Container Type | Number Collected | Filtered | Preservative                |
|---------------------------------|----------------|------------------|----------|-----------------------------|
| metals                          | 500 ml HDPE    | 1                | YES      | HNO <sub>3</sub> / HCl      |
| Gross α                         | 16 HDPE        | 1                |          | ↓                           |
| TDS                             | 125 ml HDPE    | 1                |          | cool                        |
| anions                          | ↓              | 1                |          | ↓                           |
| NH <sub>4</sub> NO <sub>3</sub> | ↓              | 1                | ↓        | cool / H <sub>2</sub> O, pH |
|                                 |                |                  |          |                             |
|                                 |                |                  |          |                             |
|                                 |                |                  |          |                             |
|                                 |                |                  |          |                             |
|                                 |                |                  |          |                             |
|                                 |                |                  |          |                             |
|                                 |                |                  |          |                             |
|                                 |                |                  |          |                             |

Write copy to front of Manager's card, to laboratory with numbers in ticket book

Figure 3. Example of a Sample Ticket GJPO 1854

### Required Information

Project Name of Project or Project Number: "GJ-12345"

Site Site location: "Landfill 3, Unit 6"

Location Exact location of sample such as borehole number, monitor well number, or distance to permanent landmarks: "MW-018"

Date Date sample was collected.

Time Time sample was collected: "1420" or "2 20 p.m."

Interval Beginning and ending depth interval of sample or time duration of sample: "2 feet to 3.8 feet," or "0800 to 1622" - dependent on sample type

Matrix Type of sample: soil, water, air, product, tissue, etc.

Sampler Name(s) initials of sampling personnel. Initials should be listed in project file for identification.

### Optional Information

Project documentation may replace optional information to avoid unnecessary writing in the field. For example, a Sampling Plan may state "all VOC samples will be collected in 40 mL glass vials" thus avoiding the need to write this for each sample. If all filtered samples use a 40 micron filter, simply put a "Y" in the filtered field. Only variances from the Sampling Plan would need to be noted on the ticket. Information duplicated on many Samples may be completed on the first ticket of the series and referred to subsequently: "Same as PIN 230" or "PIN 230"

Comments Area weather conditions, radiation levels, composite sample/ grab sample, reason for sample, additional location information, or any factors that may affect analyses. Brief location maps with a scale and north indicator are useful.

Analyte Type of analysis to be performed: "KUT," "VOC's," "Metals," "Asbestos"

Type/Size Describe type of container: Glass, HDPE, Amber, "LDPE/ 500 mL," "1L 11M Glass," "WVG/250 mL"

|      |                           |   |                        |
|------|---------------------------|---|------------------------|
| 1M   | Narrow Mouth              | A | Amber Glass or Plastic |
| VW   | Wide Mouth                | G | Glass                  |
| HDPE | High-Density Polyethylene | P | Plastic                |
| LDPE | Low-Density Polyethylene  |   |                        |

Number Collected Number of containers of each analyte.

Filtered Was sample filtered/size: Y/ "0.45 micron filter."

Preservative Cool, HCL, HNO<sub>3</sub>, Frozen, etc.

Completion of Sample Label Complete sample label as required. Remove Bar Code from ticket book and cover the "Sample Number" area on the sample label.

Figure 4. Example of a Sample Ticket  
(Back Cover of GJPO 1854)



# Standard Practice for Chain-of-Sample-Custody Control and Physical Security of Samples

## 1. Scope

1.1 This procedure describes the documentation required for tracing sample custody and the requirements for maintaining physical security of samples.

1.2 Control, storage, and disposal of samples should be addressed in the Work Plan for a particular project.

## 2. Hazard Analysis

2.1 No hazards requiring controls have been identified. Site-specific controls are available in the Health and Safety Plan for a particular project.

## 3. Referenced Documents

3.1 *GJO Environmental Procedures Catalog* (GJO 6):

GT-2(P), "Standard Practice for Sample Labeling"

## 4. Terminology

4.1 *Chain-of-sample-custody record*—A form such as the Chain of Sample Custody (GJPO 1512), or equivalent, used to document sample custody and receipt. GJPO 1512, Chain of Sample Custody, is a four-part no-carbon-required (NCR) form available as a contractor Stores issue item (Figure 1).

4.2 *Custody*—To maintain a sample in sight, immediate possession, or locked under one's personal control.

4.3 *Custody seals or tags*—Adhesive-backed strips, or metal or plastic tags, fastened to the sample container or the shipping container in such a way as to demonstrate that no tampering with the sample has occurred. Custody seals also may be manufactured in the field by using paper strips and clear plastic tape.

4.4 *Duplicate samples*—More than one sample collected from the same source location but

placed in separate containers. Also called multiple samples.

4.5 *Physical security*—Synonymous with custody but emphasizes the measures taken to prevent tampering with the samples or sampling process.

4.6 *Sample (n)*—A portion of material collected from a larger mass.

4.7 *Sample (v)*—To select and collect a sample.

4.8 *Sample number*—The unique identification number assigned by the Contractor to each sample and attached to, or written on, the sample label or sample container. The sample number will normally consist of three alpha and three numeric characters and will have both eye-readable and bar-code portions. See Procedure GT-2(P), "Standard Practice for Sample Labeling," Section 3.1, on how to obtain sample numbers.

4.9 *Split sample*—A sample that has been subdivided into two or more parts, each part representative of the original sample.

## 5. Significance and Use

5.1 All contractor personnel shall use this procedure for chain-of-sample-custody control and physical security unless an approved alternate procedure is included or referenced in the official project records.

5.2 Projects that do not require sample custody documentation may use other types of sample logs for documenting sample information.

## 6. Materials

6.1 Chain of Sample Custody form (GJPO 1512) or equivalent.

6.2 Ballpoint pen with waterproof, reproducible ink.

6.3 Custody seals or tags.

[illegible]

Figure 1. Chain of Sample Custody Form (GJPO 1512)

6.4 Clear plastic tape (normally 2 inches wide).

6.5 Padlocks, receptacles, containers, and/or enclosures as appropriate to provide physical security of the samples.

## 7. Chain-of-Sample-Custody Procedure

7.1 The sampler shall complete the chain-of-sample-custody record during or after sample collection. Use the current version of GJPO 1512 unless a project specifies a different form or specifies that no chain-of-sample-custody is required.

7.2 Use waterproof, reproducible ink to complete the form.

7.3 The initiator of the form is responsible for legibility of all entries other than signatures.

7.4 General instructions for completing GJPO 1512 are printed on the back of the form (Figure 2). The following items provide additional information to the instructions.

7.4.1 The preservation method may be specified in the remarks column.

7.4.2 *Condition Received*—Examples of conditions to note could include broken container, lid off, leaking fluid, etc.

7.4.3 *Relinquished by/Received by*—When the samples are physically transferred from one person to another, or from a person to a shipper, the relinquisher and receiver shall sign the appropriate block, with the date and time of sample transfer. The relinquishers, by signing, verify that the samples have been within their custody.

7.4.3.1 It is each signatory's responsibility to write the signature legibly.

7.4.3.2 The relinquisher retains a copy of the form.

7.4.3.3 Noncontractor employees are not required to sign the form (e.g., employees of shipping companies).

7.5 The following is the minimum information required on the form to ensure sample identification:

7.5.1 Date chain-of-sample-custody form was prepared;

7.5.2 Project name;

7.5.3 Sampler's printed name; and

7.5.4 Sample number.

7.6 Complete all information blocks or label the blocks "NA" for "not applicable". Line through unused portions of items 6 through 13 with a single line, and initial and date the line (Figure 3).

7.7 When samples will be transported by a non-Contractor shipper, use custody seals or tags to seal the individual sample containers or the inner or outer shipping carton.

7.7.1 When seals are applied to the sample container, they must not obscure the information on the sample label.

7.7.2 Securely wrap or fasten shipping containers prior to application of the custody seals. The seals are inherently fragile and will not withstand pressure from an inadequately packaged container. Seal all possible access flaps or lids of the shipping container.

7.7.3 Enter the date the samples are sealed and sign the custody seals or tags as shown below. Clear plastic tape may be applied over the seals for protection.

### CUSTODY SEAL

Date \_\_\_\_\_

Signature \_\_\_\_\_

Example of Custody Seal

7.8 The original chain-of-sample-custody record shall accompany the samples until they are received by the laboratory.

7.9 Unless otherwise specified by the project, the chain-of-sample-custody record shall be maintained as part of the project records.

## Chain-of-Sample Custody

1. Page \_\_\_\_ of \_\_\_\_: Indicates sequence and total number of pages.
2. Date: Date the chain-of-custody record was prepared.
3. Project Name: The project name or title.
4. Site Location: The location of the project site.
5. Sampler: The printed name of the person who collected the samples.
6. Sample No.: The unique three-letter, three-digit number generated by GJO.
7. Date: Date the sample was collected.
8. Time: The time the sample was collected.
9. Sample Location: The location at which the sample was taken; e.g., well number, grid location, or survey coordinate.
10. Sample Matrix: The sample matrix, e.g., soil, sludge, water, air, or filter.
11. Container: The type of container; e.g., write 40-mL glass in the slanted column. Write the number of containers of a given type on the corresponding horizontal line.
12. Remarks: Any remarks, as appropriate; preservation method required, e.g., acidified < 2 pH.
13. Condition Received: For use by laboratory personnel, to note any damage to sample or container.
14. Relinquished by/Received by: Signatures of relinquishers and receivers, with date and time of sample transfer.
15. Method of Shipment: The method of shipment, e.g., Federal Express, bus line, etc.
16. Laboratory/Destination: The place the samples were shipped for analysis, storage, or other purposes.
17. Airbill or Receipt Number: For use with airbills or receipts from contract shippers.
18. For Use by Contract Laboratories Only: For use by laboratories other than the Grand Junction Office (GJO). Receiver to sign, date, and return this form to GJO by mail or with analytical data package.

**General:** The purpose of this form is to document sample custody and receipt. GJO assumes no responsibility for samples not in the custody of GJO personnel.

The users of this form are responsible for completing the form by using a waterproof, reproducible ink.

The users of this form are responsible for legibility of all entries.

All information blocks must be completed or marked as "NA" for "Not Applicable." Unused portions of the form must be lined out with a single line, initialed, and dated.

Figure 2. Instructions for Completing Chain-of-Sample-Custody Form (Reverse Side of GJPO 1512)



## Grand Junction Office

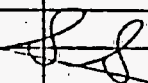
2577 N 3/4 Road  
Grand Junction, Colorado 81503  
Telephone (970) 248-6000

## Chain-of-Sample Custody

1. Page 1 of 12. Date 12/3/983. Project Name OU14. Site Location Monticello, UT

## 11. Containers

5. Sampler (print name) Sam Sampler

| 6. Sample No.                                                                                                      | 7. Date | 8. Time | 9. Sample Location | 10. Sample Matrix | 11. Containers             |        |                             |                               | 12. Remarks                               | 13. Condition Received |  |
|--------------------------------------------------------------------------------------------------------------------|---------|---------|--------------------|-------------------|----------------------------|--------|-----------------------------|-------------------------------|-------------------------------------------|------------------------|--|
| NAA 001                                                                                                            | 12/3/98 | 1:00 pm | Well 5A            | Water             | 3                          |        |                             |                               | Re-226 pH < 2 HNO <sub>3</sub>            | ok                     |  |
|                                                                                                                    |         |         |                    |                   | 1                          |        |                             |                               | metals pH < 2 HNO <sub>3</sub> Unfiltered |                        |  |
|                                                                                                                    |         |         |                    |                   |                            | 3      |                             |                               | PCB, Unfiltered, Cool                     |                        |  |
|                                                                                                                    |         |         |                    |                   |                            |        | 1                           |                               | BOD, Cool                                 |                        |  |
| <br><u>12/3/98</u>                |         |         |                    |                   |                            |        |                             |                               |                                           |                        |  |
| 14. Relinquished by (signature)                                                                                    |         |         |                    |                   | Date                       | Time   | Relinquished by (signature) |                               |                                           |                        |  |
| <u>Sam Sampler</u>                                                                                                 |         |         |                    |                   | 12/3/98                    | 1:30 p |                             |                               |                                           |                        |  |
| Received by (signature)                                                                                            |         |         |                    |                   | Date                       | Time   | Received by (signature)     |                               |                                           |                        |  |
| <u>Logan Receipt</u>                                                                                               |         |         |                    |                   | 12/3/98                    | 1:30 p |                             |                               |                                           |                        |  |
| 15. Method of Shipment                                                                                             |         |         |                    |                   | 16. Laboratory/Destination |        |                             | 17. Airbill or Receipt Number |                                           |                        |  |
| 18. For Contract Laboratories Only—Receiver to sign, date, and return form by mail or with analytical data package |         |         |                    |                   |                            |        |                             |                               |                                           |                        |  |
| Company Name                                                                                                       |         |         |                    |                   | Received by                |        |                             | Date                          |                                           |                        |  |

GJO 1112  
5/97

Preparation instructions on back of form.

Distribution: Original accompanies shipment, copies to relinquisher.

Figure 3. Example of Completed Chain-of-Sample-Custody Form

## **8. Physical Security of Samples and Sampling Process**

8.1 The sampler must maintain physical security of the samples, sampling process, and equipment by physical possession, visual contact, or seals or locks to prevent tampering. Because the procedures for physical security are unique to each sampling situation, only guidelines can be given.

8.1.1 Lock the sampling device when unattended. For example, when using an unattended autosampler to collect samples for a period of time, the device must be locked or secured to maintain physical security.

8.1.2 Store samples in a locked storage area. For example, when collecting samples for a period of time before transporting to the laboratory, lock the samples in a secure storage area or in an area with controlled access such as a locked vehicle or locked field office.

8.1.3 Use security seals where appropriate. Although security seals do not provide physical security, the seals are evidence that the samples or sampling process was not tampered with while unattended.

8.1.4 Use best professional judgment when providing physical security of the samples or sampling process. The sampler should be knowledgeable of the programmatic requirements for the samples and provide the appropriate degree of physical security.

8.2 Document in field logs, or other project documents, the type of physical security used.

## **9. Keywords**

9.1 Chain-of-sample-custody record, form, laboratory, physical security, samples, and shipper.



## ***Environmental Procedures Catalog***

### **Document Addition/Revision**

**Procedure Title:** Standard Practice for Equipment Decontamination, [GT-7(P)], Rev. 0, 12/98

**Requester:** Tim Bartlett, Field Supervisor

**Justification:** To establish project specific policy regarding disposal of equipment decontamination fluids.

**Proposed Change:** Equipment decontamination fluids from millsite and downgradient alluvial ground water sampling wells will be collected and disposed in Pond 4 or another designated decontamination facility. Decontamination fluids from bedrock ground water sampling wells will be managed according to bedrock purge water management requirements specified in Section 4.2.1 of the *MMTS Operable Unit III, Interim Remedial Action Surface Water and Ground Water Monitoring Program*.

#### **Authorization for Changes to Catalog Procedures**

☐ New Document                      ☐ Change to Existing Procedure                      ☐ Adopt Procedure

Procedure Number Assigned \_\_\_\_\_

Procedure Title \_\_\_\_\_

Approval for Inclusion in Environmental Procedures Catalog:

\_\_\_\_\_  
Environmental Procedures Advisory Committee Chair

\_\_\_\_\_  
Date

#### **Authorization for Project Specific Modification to Existing Catalog Procedures**

Project Specific Change for *MMTS Operable Unit III, Interim Remedial Action Surface Water and Ground Water Monitoring Program, MAC-MSGRAP 1.3.5-2*

Effective Date April 5, 1999

Reviewed By

*Ann Campbell*  
Technical Author or  
Proficient Designee

4-6-99  
Date

Approved By

*Keith McCluskey*  
Manager or Designee

4/6/99  
Date

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**Technical Comments on ASTM D5088-90****Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites****Summary of ASTM D5088-90**

The purpose of this practice is to provide guidance for the decontamination of field equipment used in the sampling of soils, soil gas, sludges, surface water, and ground water at nonradioactive waste sites.

**Additions Applicable to Operating Contractor and its Subcontractors**

This standard guide shall be referenced when preparing sampling and analysis plans for site investigation activities. The guidance provided may be superseded by other project documents, such as Project Safety Plans or Project Quality Assurance Plans.

The following sections shall be interpreted in conjunction with the current published version of the ASTM guide. The sections shall be interpreted in numerical order, using the published version as the base document for reference.

**4. Summary of Practice**

4.1.1 Some nonsample contacting equipment may not require decontamination due to limited use and/or site conditions that do not pose a risk.

4.2.8 The information included in an equipment decontamination protocol, as well as how the information is presented in site plans should be determined on a site specific basis.

**7. Procedure for Sample Contacting Equipment**

7.2.9 When samples will undergo inorganic analyses, the use of an inorganic desorbing agent may not be required if the QA/QC program documents that the decontamination protocol is sufficient for the sampling methods being used.

**8. Quality Assurance/Quality Control**

8.1.4 The frequency for the minimum number of samples to demonstrate completeness of decontamination for QA/QC purposes may be either increased or decreased on a site specific basis based on an evaluation of QA/QC samples and project specific objectives.

**9. Report**

9.1.9 The activities associated with reporting equipment decontamination should be determined on a site specific basis based on the specific objectives of each project.

**10. Hazard Analysis**

10.1 Exposure to hazardous substances and chemicals is possible during performance of this task. The applicable site Health and Safety Plan (HSP) or Project Safety Plan (PSP) shall be used for all decontamination work.

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## Standard Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites<sup>1</sup>

This standard is issued under the fixed designation D 5088; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reappraisal. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reappraisal.

### 1. Scope

1.1 This practice covers the decontamination of field equipment used in the sampling of soils, soil gas, sludges, surface water, and ground water at waste sites which are to undergo both physical and chemical analyses.

1.2 This practice is applicable only at sites where chemical (organic and inorganic) wastes are a concern and is not intended for use at radioactive or mixed (chemical and radioactive) waste sites.

1.3 Procedures are included for the decontamination of equipment which comes into contact with the sample matrix (sample contacting equipment) and for ancillary equipment that has not contacted the portion of sample to be analyzed (non-sample contacting equipment).

1.4 This practice is based on recognized methods by which equipment may be decontaminated. When collecting environmental matrix samples, one should become familiar with the site specific conditions. Based on these conditions and the purpose of the sampling effort, the most suitable method of decontamination can be selected to maximize the integrity of analytical and physical testing results.

1.5 This practice is applicable to most conventional sampling equipment constructed of metallic and synthetic materials. The manufacturer of a specific sampling apparatus should be contacted if there is concern regarding the reactivity of a decontamination rinsing agent with the equipment.

1.6 *This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

### 2. Referenced Document

#### 2.1 ASTM Standard:

D 653 Terminology Relating to Soil, Rock, and Contained Fluids<sup>2</sup>

### 3. Terminology

#### 3.1 Definitions:

3.1.1 *contaminant*—an undesirable substance not normally present or an unusually high concentration of a naturally occurring substance in water or soil.

3.1.2 *control rinse water*—water used for equipment washing and rinsing having a known chemistry.

3.1.3 *decontamination*—the process of removing or reducing to a known level undesirable physical or chemical constituents, or both, from a sampling apparatus to maximize the representativeness of physical or chemical analyses proposed for a given sample.

3.1.4 *non-sample contacting equipment*—related equipment associated with the sampling effort, but that does not directly contact the sample (for example, augers, drilling rods, excavations machinery).

3.1.5 *quality assurance/quality control (QA/QC)*—the efforts completed to evaluate the accuracy and precision of a sampling or testing procedure, or both.

3.1.6 *sample contacting equipment*—equipment that comes in direct contact with the sample or portion of sample that will undergo chemical analyses or physical testing (for example, ground water well bailer, split-spoon sampler, soil gas sampling probe).

3.1.7 For definitions of other terms used in this practice, see Terminology D 653.

### 4. Summary of Practice

4.1 Two different procedures are presented for the decontamination of sample-contacting and non-sample contacting equipment. The procedures have been developed based on a review of current state and federal guidelines, as well as a summary of commonly employed procedures. In general, sample contacting equipment should be washed with a detergent solution followed by a series of control water, desorbing agents and deionized water rinses. Nonsample contacting equipment should be washed with a detergent solution and rinsed with control water. Although such techniques may be difficult to perform in the field, they may be necessary to most accurately evaluate low concentrations of the chemical constituent(s) of interest.

4.2 Prior to initiating a field program that will involve equipment decontamination, a site specific equipment decontamination protocol should be prepared for distribution to the individuals involved with the particular sampling program. Information to be presented in the protocol should include:

4.2.1 Site location and description,

4.2.2 Statement of the sampling program objective and desired precision and accuracy, that is, is sampling effort for gross qualitative evaluation or for trace concentration, parameter specific evaluations,

4.2.3 Summary of available information regarding soil types, hydrogeology and anticipated chemistry of the materials to be sampled.

<sup>1</sup> This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Foundations and is the direct responsibility of Subcommittee D18.14 on Geotechnics of Management.

Current edition approved June 29, 1990. Published September 1990.

<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.



4.2.4 Listing of equipment to be used for sampling and materials needed for decontamination.

4.2.5 Detailed step by step procedure for equipment decontamination for each piece or type of equipment to be utilized and procedures for rinse fluids containment and disposal as appropriate.

4.2.6 Summary of QA/QC procedures and QA/QC samples to be collected to document decontamination completeness including specific type of chemical analyses and their associated detection limit, and

4.2.7 Outline of equipment decontamination verification report.

## 5. Significance and Use

5.1 An appropriately developed, executed and documented equipment decontamination procedure is an integral and essential part of waste site investigations. The benefits of its use include:

5.1.1 Minimizing the spread of contaminants within a study area and from site to site,

5.1.2 Reducing the potential for worker exposure by means of contact with contaminated sampling equipment, and

5.1.3 Improved data quality and reliability.

5.2 This practice is not a substitute for a well-documented Quality Assurance/Quality Control (QA/QC) program. Because the ultimate test of a decontamination procedure is its ability to minimize erroneous data, a reasonable QA/QC program must be implemented.

5.3 This practice may not be applicable to all waste sites. When a sampling effort is completed to determine only the general range of chemical concentrations of interest less rigorous decontamination procedures can be adequate. Investigators should have the flexibility to modify the decontamination procedures with due consideration for the sampling objective or if QA/QC documentation supports alternative decontamination methods.

5.4 At sites where the reactivity of sampling equipment to decontamination washes creates concern for the generation of undesirable chemical by-products, the use of dedicated sampling equipment should be considered.

5.5 This practice, where applicable, should be used before, between, and after the completion of sampling events.

## 6. Reagents

6.1 *Detergent*, non-phosphate detergent solution.<sup>3</sup>

6.2 *Acid rinse (inorganic desorbing agent)*, 10 % nitric or hydrochloric acid solution-made from reagent grade nitric or hydrochloric acid and deionized water (1 % is to be applied to low-carbon steel equipment).

6.3 *Solvent rinse (organic desorbing agent)*, isopropanol, acetone, or methanol; pesticide grade.

6.4 *Control rinse water*, preferably from a water system of known chemical composition.

6.5 *Deionized water*, organic-free reagent grade.

## 7. Procedure for Sample Contacting Equipment

7.1 At a minimum, sample contacting equipment should

be washed with a detergent solution and rinsed with control water.

7.2 For programs requiring more rigorous decontamination to meet the sampling or QA/QC objectives, the following procedures are indicated:

7.2.1 Wash with detergent solution, using a brush made of inert material to remove any particles or surface film.

7.2.1.1 For equipment that, because of internal mechanism or tubing cannot be adequately cleaned with a brush, the decontamination solutions should be circulated through the equipment.

7.2.2 Rinse thoroughly with control water.

7.2.3 Rinse with an inorganic desorbing agent (may be deleted if samples will not undergo inorganic chemical analysis).

7.2.4 Rinse with control water.

7.2.5 Rinse with organic desorbing agent (may be deleted if samples will not undergo organic chemical analyses).

7.2.6 Rinse with deionized water.

7.2.7 Allow equipment to air dry prior to next use.

7.2.8 Wrap equipment for transport with inert material (aluminum foil or plastic wrap) to direct contact with potentially contaminated material.

### 7.3 Nonsample Contact Equipment:

7.3.1 Clean the equipment with portable power washer or steam cleaning machine. Alternatively, hand wash with brush using detergent solution.

7.3.2 Rinse with control water.

7.3.3 The more rigorous decontamination procedures may be employed if necessary to meet sampling or QA/QC objectives.

7.4 Depending on site conditions, it may be appropriate to contain spent decontamination rinse fluids. If this is the case the appropriate vessel<sup>4</sup> for fluid containment should be used depending on the ultimate disposition of the material.

7.5 Depending on site conditions, it may be desirable to perform all equipment decontamination at a centralized location as opposed to the location where the equipment was used. If this is the case, care must be taken to transport the equipment to the decontamination area such that the spread of contaminants is minimized.

## 8. Quality Assurance/Quality Control

8.1 It is important to document the effectiveness of the decontamination procedure. To that end the projects QA/QC program should include provisions for the collection of samples to evaluate the completeness of a specific decontamination procedure. This could include:

8.1.1 Collection of rinse or wipe samples before the initial equipment decontamination prior to its use for sampling to establish a base line level of contaminants residing on or in the equipment.

8.1.2 Collection of final rinse or wipe samples after equipment decontamination following its use, and

8.1.3 The frequency of sampling to demonstrate the completeness of equipment decontamination is dependent upon objectives of the project as they relate to QA/QC. At a

<sup>3</sup> Alquinox or Liquinox or similar solution has been found suitable for this purpose.

<sup>4</sup> A drum approved by the Department of Transportation or similar container has been found suitable for this purpose.

minimum it is recommended after every ten decontamination washings.

## 9. Report

9.1 The activities completed for each equipment decontamination should be documented in writing. Included in this report should be the following information:

- 9.1.1 Site location, date, time, and weather,
- 9.1.2 Sample location where equipment was employed,
- 9.1.3 Location where decontamination was performed,
- 9.1.4 Individuals performing the decontamination,

- 9.1.5 Decontamination procedures,
- 9.1.6 Source of materials (solutions) used for decontamination,
- 9.1.7 Handling of rinse fluids and accumulates solids, if any, and
- 9.1.8 QA/QC sampling performed and analytical results of QA/QC samples whether completed in the field or laboratory subsequent to sampling event.

## 10. Keywords

- 10.1 contaminant; decontamination; sampling; waste

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**Appendix B**  
**Well Completion Diagrams**

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# MONITORING WELL COMPLETION LOG 82-07

Project: Monticello Mill Tailings Site  
 Location: Monticello, Utah  
 Site: 1700 ft. Southeast of East Pile  
 Total Depth (ft.): 20.0  
 Auger Stem Size (in.): Unknown

North Coordinate (ft.): 10006.19  
 East Coordinate (ft.): 24669.49  
 Ground Elevation (ft. MSL): 6784.50  
 Measuring Point Elev. (ft.): 6785.70  
 Auger Head Size (in.): Unknown

Date Drilled: 07/07/82  
 Drilling Method: Hollow Stem Auger  
 Sampling Method: Split Barrel  
 Development Date: Unknown  
 Water Level (ft. BGL): Unknown

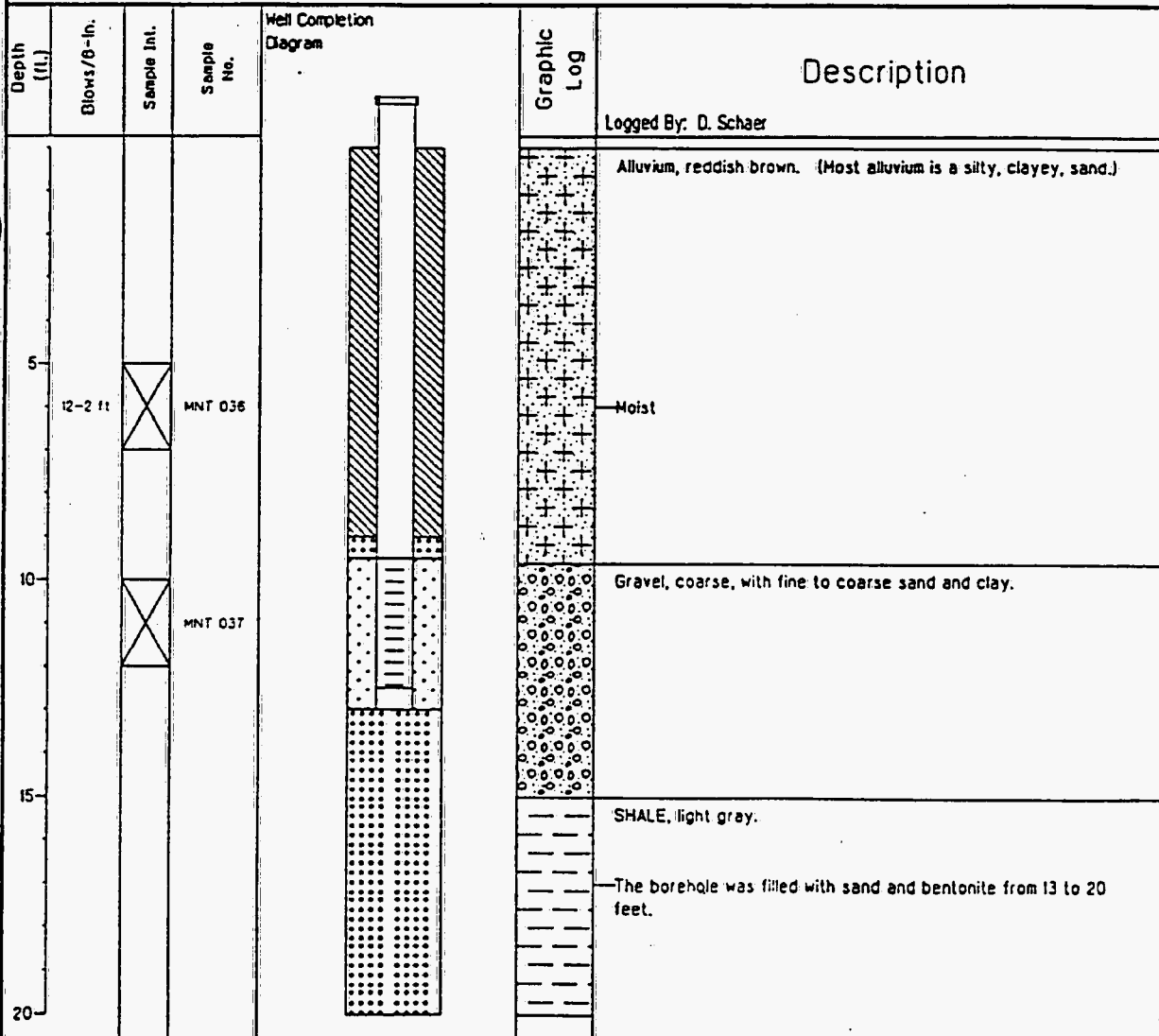
**WELL INSTALLATION**  
 Blank Casing: 2.0 in. PVC Sched.40  
 Screen: 2.0 in. PVC Sched.40  
 Slot Size: Unknown  
 End Cap: PVC  
 Grout: Cement  
 Sealant: Bentonite Pellets  
 Sand Pack (U): Unknown  
 Sand Pack (L): NA

**INTERVAL (ft.)**  
 +12 to 9.5  
 9.5 to 12.5  
 12.5 to 13.0  
 1.0 to 9.0  
 9.0 to 9.5  
 9.5 to 13.0

**BIT SIZES (in.)**  
 Not Applicable

**SURFACE CASING (ft.)**  
 Not Applicable

Comments:



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Date Drawn: 03/23/1993

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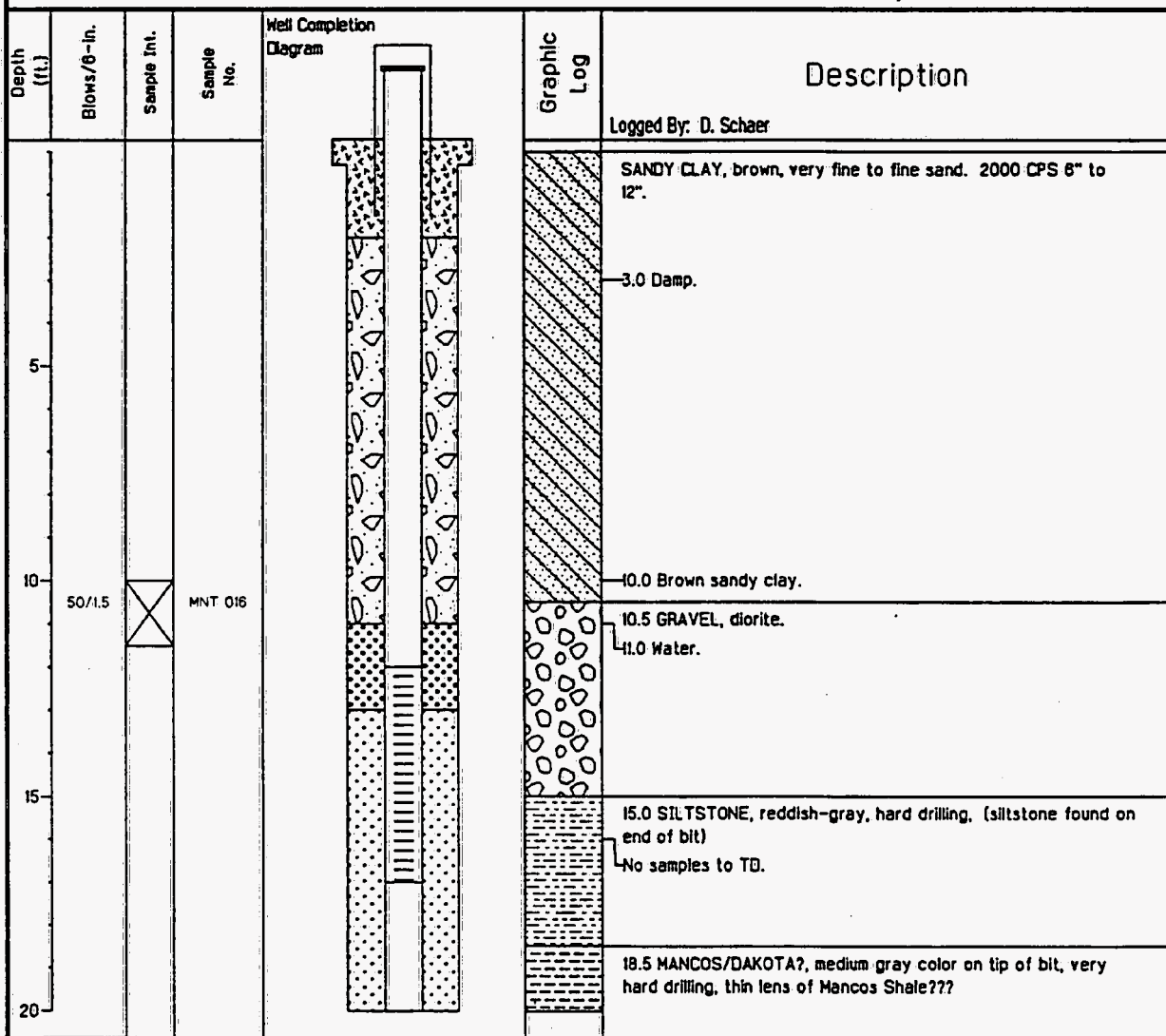
# MONITORING WELL COMPLETION LOG 82-08

Project: MONTICELLO MILL TAILINGS SITE North Coordinate (ft.): 10204.8 Date Drilled: 6/19/82  
 Location: Monticello, Utah East Coordinate (ft.): 24876.2 Drilling Method: Hollow Stem Auger  
 Site: Peripheral Property, downgradient of Millsite Ground Elevation (ft. MSL): 6785.3 Sampling Method: Split Spoon  
 Total Depth (ft.): 20.0 Measuring Point Elev. (ft.): 6787.3 Development Date: NA  
 Auger Stem Size (in.): NA Auger Head Size (in.): 8.0 Water Level (ft. BMP): 11.0, 6/19/82

WELL INSTALLATION INTERVAL (ft.) BIT SIZES  
 Blank Casing: 2 in. SCH. 40 PVC +2.0 to 12.0 Not Applicable  
 Screen: 2 in. 2 in. SCH. 40 PVC 12.0 to 17.0  
 Slot Size: 0.008 in.  
 End Cap: SCH. 40 PVC 17.0 to 20.0  
 Grout: Soil 2.0 to 11.0  
 Sealant: Bentonite 11.0 to 13.0  
 Sand Pack (U): #50/30 Frac. sand 13.0 to 20.0  
 Sand Pack (L): NA

SURFACE CASING  
 Not Applicable

Comments:



File: 82-08.LOG

Date Drawn: 11/21/1996

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# MONITORING WELL COMPLETION LOG 82-09

Project: MONTICELLO MILL TAILINGS SITE North Coordinate (ft.): 9485.7 Date Drilled: 6/18/82  
 Location: Monticello, Utah East Coordinate (ft.): 25825.2 Drilling Method: Hollow Stem Auger  
 Site: Peripheral Property, downgradient of Millsite Ground Elevation (ft. MSL): 6765.3 Sampling Method: Split Spoon  
 Total Depth (ft.): 14.0 Measuring Point Elev. (ft.): 6765.9 Development Date: NA  
 Auger Stem Size (in.): NA Auger Head Size (in.): 8.0 Water Level (ft. BMP): Dry?, 6/18/82

| WELL INSTALLATION |                         | INTERVAL (ft.) | BIT SIZES      |
|-------------------|-------------------------|----------------|----------------|
| Blank Casing:     | 2 in. SCH. 40 PVC       | +0.6 to 9.0    | Not Applicable |
| Screen:           | 2 in. 2 in. SCH. 40 PVC | 9.0 to 13.75   |                |
| Slot Size:        | 0.008 in.               |                |                |
| End Cap:          | SCH. 40 PVC             | 13.75 to 14.0  | SURFACE CASING |
| Grout:            | Soil                    | 2.0 to 8.0     | Not Applicable |
| Sealant:          | Bentonite               | 8.0 to 9.0     |                |
| Sand Pack (U):    | #50/30 Frac. sand       | 9.0 to 14.0    |                |
| Sand Pack (L):    | NA                      |                |                |



Comments:

| Depth (ft.)            | Blows/6-in. | Sample Int. | Sample No. | Well Completion Diagram | Graphic Log | Description                                                                                   |
|------------------------|-------------|-------------|------------|-------------------------|-------------|-----------------------------------------------------------------------------------------------|
|                        |             |             |            |                         |             | Logged By: D. Schaer                                                                          |
|                        |             |             |            |                         |             | SANDY SILT, reddish brown, soil.                                                              |
| 5                      | 9/2         | X           | MNT 010    |                         |             | 5.0 Same as above.                                                                            |
| 6                      | 6/2         | X           | MNT 011    |                         |             | 8.0 CLAYEY SAND, 75% very fine to medium grained angular sand, 25% clay, poorly consolidated. |
| 10                     |             |             |            |                         |             | 9.0 Grades to yellow-brown sand.                                                              |
|                        |             |             |            |                         |             | 12.0 DAKOTA SANDSTONE, hard.                                                                  |
| 15                     |             |             |            |                         |             | Total depth at 14.0 feet.                                                                     |
| 20                     |             |             |            |                         |             |                                                                                               |
| File: 82-09.LOG        |             |             |            |                         |             | Page 1 of 1                                                                                   |
| Date Drawn: 11/21/1996 |             |             |            |                         |             |                                                                                               |

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# MONITORING WELL COMPLETION LOG 82-20

| Depth<br>(Ft.) | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                        | Graphic<br>Log                                                                    | Description               |
|----------------|-------------|-------------|---------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|---------------------------|
|                |             |             |               |  |  |                           |
|                |             |             |               |                                                                                   |                                                                                   | 22.0 DAKOTA SANDSTONE.    |
|                |             |             |               |                                                                                   |                                                                                   | Total depth at 22.5 feet. |
| 25             |             |             |               |                                                                                   |                                                                                   |                           |
| 30             |             |             |               |                                                                                   |                                                                                   |                           |
| 35             |             |             |               |                                                                                   |                                                                                   |                           |
| 40             |             |             |               |                                                                                   |                                                                                   |                           |
| 45             |             |             |               |                                                                                   |                                                                                   |                           |
| 50             |             |             |               |                                                                                   |                                                                                   |                           |

File: 82-20.LOG

Date Drawn: 11/21/1996

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# **MONITORING WELL COMPLETION LOG 83-70**

Project: Monticello Mill Tailings Site  
 Location: Monticello, Utah  
 Site: Downgradient, just east of Millsite  
 Total Depth (ft.): 186.0  
 Auger Stem Size (in.): NA

North Coordinate (ft.): 10,339.3  
 East Coordinate (ft.): 24,019.0  
 Ground Elevation (ft. MSL): 6796.2  
 Measuring Point Elev. (ft.): 6796.6  
 Auger Head Size (in.): NA

Date Drilled: 05/11/83 - 05/17/83  
 Drilling Method: Mud Rotary  
 Sampling Method: Rotary Cuttings/Core  
 Development Date: Unknown  
 Water Level (ft. BGL): Unknown

**WELL INSTALLATION**  
 Blank Casing: 4.0 in. SCH 40 PVC  
 Screen: 4.0 in. SCH 40 PVC  
 Slot Size: 0.03 in.  
 End Cap: 4.0 in. SCH 40 PVC  
 Grout: NA  
 Sealant: 1/4 in. Bentonite Pellets  
 Sand Pack (U): Well Sand  
 Sand Pack (L): NA

**INTERVAL (ft.)**  
 +0.4 to 46.5  
 46.5 to 166.5  
 166.5 to 167.0  
 30.0 to 40.0  
 40.0 to 186.0

**BIT SIZES (in.)**  
 9.875 in. Rotary from 0.0 to 30.0  
 7.875 in. Core from 30.0 to 175.0  
 4.875 in. Core from 175.0 to 186.0  
**SURFACE CASING (ft.)**  
 8.625 in. Steel from +0.9 to 30.0  
 Cement from 0.0 to 30.0

Comments: No sealant in annulus above the bentonite.

| Depth<br>(ft.)         | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                   |
|------------------------|-------------|-------------|---------------|----------------------------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        |             |             |               |                            |                | Logged By: P. Kearn                                                                                                                                           |
| 5                      |             |             |               |                            |                | UNCONSOLIDATED ALLUVIUM. Upper portion primarily clay, grading downward to a sandy gravel.                                                                    |
| 10                     |             |             |               |                            |                | 10.0 Hole making water.                                                                                                                                       |
| 15                     |             |             |               |                            |                |                                                                                                                                                               |
| 20                     |             |             |               |                            |                | 20.0 DAKOTA SANDSTONE, Interbedded SANDSTONE and SHALE stringers. SANDSTONE, fine grained, well cemented. SHALE, dark gray, gritty.                           |
| 25                     |             |             |               |                            |                |                                                                                                                                                               |
| 30                     |             |             |               |                            |                | 30.0 SANDSTONE, light tan, fine grained, well cemented, hair-like carbonaceous stringers, soft sediment deformation.                                          |
| 35                     |             |             |               |                            |                | 31.0 SHALE, dark gray, minor amount of sand.                                                                                                                  |
| 40                     |             |             |               |                            |                | 36.0 3-in. SANDSTONE stringer.                                                                                                                                |
| 45                     |             |             |               |                            |                | 37.5 COAL, shaley.                                                                                                                                            |
| 50                     |             |             |               |                            |                | 39.0 SHALE, silty, medium grained, increase in sand with depth, carbonaceous.                                                                                 |
|                        |             |             |               |                            |                | 45.0 SANDSTONE, light gray, subangular grains, moderately to poorly sorted, pyrite nodules, carbonaceous stringers, soft sediment deformation (bioturbation). |
| File: 8370.LOG         |             |             |               |                            |                | Page 1 of 4                                                                                                                                                   |
| Date Drawn: 03/02/1994 |             |             |               |                            |                |                                                                                                                                                               |

# MONITORING WELL COMPLETION LOG 83-70

| Depth<br>(ft.) | Blows/6-in. | Sample Int. | Sample No. | Well Completion Diagram | Graphic Log            | Description                                                                                                                                                        |
|----------------|-------------|-------------|------------|-------------------------|------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                |             |             |            |                         |                        |                                                                                                                                                                    |
| 55             |             |             |            |                         |                        | Extensive fractures from 51.0 to 53.0 feet.                                                                                                                        |
|                |             |             |            |                         |                        | 54.0 SANDSTONE, Conglomeratic, coarse grained, angular grains, well cemented.                                                                                      |
| 60             |             |             |            |                         |                        | 58.0 BURRO CANYON FORMATION, SILTSTONE, green, about 2-inch thick.                                                                                                 |
|                |             |             |            |                         |                        | 58.2 SANDSTONE, fine grained, poorly sorted, friable, glauconitic stain. Hole making water.                                                                        |
| 65             |             |             |            |                         |                        | 60.0 SANDSTONE, white, fine grained, well rounded grains, well sorted, friable to moderately cemented. 2-in. clay zone with scattered very small pebble fragments. |
| 70             |             |             |            |                         |                        |                                                                                                                                                                    |
| 75             |             |             |            |                         |                        | Well making water, approximately 10 to 50 gpm.                                                                                                                     |
| 80             |             |             |            |                         |                        | 80.0 SANDSTONE, medium grained, well rounded, well sorted, moderately to well cemented, stringers of dark minerals.                                                |
| 85             |             |             |            |                         |                        |                                                                                                                                                                    |
|                |             |             |            |                         |                        | 88.0 PEBBLE CONGLOMERATE, medium- to coarse-grained sand matrix with 2% dark minerals, rounded, moderately cemented.                                               |
| 90             |             |             |            |                         |                        | 88.0 SANDSTONE, medium grained, rounded grains, moderately sorted, moderately to well cemented, stringers of dark minerals, trace of pyrite.                       |
| 95             |             |             |            |                         |                        |                                                                                                                                                                    |
| 100            |             |             |            |                         |                        | 99.0 PEBBLE CONGLOMERATE, medium- to coarse-grained sandstone matrix, well cemented, minor clay stringers.                                                         |
|                |             |             |            |                         | File: 8370.LOG         | Page 2 of 4                                                                                                                                                        |
|                |             |             |            |                         | Date Drawn: 03/02/1994 |                                                                                                                                                                    |



# MONITORING WELL COMPLETION LOG 83-70

| Depth<br>(Ft.) | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                               |
|----------------|-------------|-------------|---------------|----------------------------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                |             |             |               |                            |                |                                                                                                                                                                                                           |
| 105            |             |             |               |                            |                | 104.0 SANDSTONE, salt and pepper color, medium grained, rounded grains, moderately sorted, scattered small pebbles (2-3 mm).                                                                              |
| 110            |             |             |               |                            |                | 110.0 SANDSTONE, white, medium grained, moderately sorted, well cemented.                                                                                                                                 |
| 115            |             |             |               |                            |                |                                                                                                                                                                                                           |
| 120            |             |             |               |                            |                |                                                                                                                                                                                                           |
| 125            |             |             |               |                            |                | 123.0 Interbedded CLAY and SILTSTONE layers, light green, from 123.0 TO 124.0 feet. Lost circulation. PEBBLE CONGLOMERATE, with fine-grained sand and clay matrix, some graded bedding (8-in. thickness). |
| 130            |             |             |               |                            |                | 125.0 Interbedded, CLAY, light gray, and SANDSTONE, fine grained, with clay matrix.                                                                                                                       |
| 135            |             |             |               |                            |                | 131.0 SANDSTONE, medium grained, well rounded, moderately sorted, scattered pebbles throughout.                                                                                                           |
| 140            |             |             |               |                            |                |                                                                                                                                                                                                           |
| 145            |             |             |               |                            |                | 142.0 PEBBLE CONGLOMERATE, medium grained, sand matrix.                                                                                                                                                   |
| 150            |             |             |               |                            |                | 149.0 SANDSTONE, moderately cemented, cross bedding.                                                                                                                                                      |

File: 8370.LOG

Date Drawn: 03/02/1994

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# MONITORING WELL COMPLETION LOG 83-70

| Depth<br>(Ft.) | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                            |
|----------------|-------------|-------------|---------------|----------------------------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 155            |             |             |               |                            |                | 155.0 SANDSTONE, medium grained, salt and peeper, friable.                                                                                                                             |
| 160            |             |             |               |                            |                | 158.0 PEBBLE CONGLOMERATE, with sandstone matrix, moderately rounded to subangular, moderately sorted, moderately cemented, friable.                                                   |
| 180            |             |             |               |                            |                | 180.0 Interbedded PEBBLE CONGLOMERATE and SANDSTONE, medium grained, subangular to moderately rounded, moderately sorted, pebbles scattered throughout interval (180.0 to 180.5 feet). |
| 185            |             |             |               |                            |                | 188.0 Lower CONGLOMERATE layer is highly calcareous with limestone fragments.                                                                                                          |
| 170            |             |             |               |                            |                | 188.0 SANDSTONE, with clay or mudstone stringers.                                                                                                                                      |
| 170            |             |             |               |                            |                | 170.0 MORRISON FORMATION, MUDDSTONE, silty, greenish, calcareous.                                                                                                                      |
| 175            |             |             |               |                            |                | 172.5 MUDDSTONE, reddish, phyllitic sheen along fracture planes. Lost core from 172.5 to 173.5 feet.                                                                                   |
| 180            |             |             |               |                            |                | 182.0 MUDDSTONE, greenish, calcareous, less silt than above.                                                                                                                           |
| 185            |             |             |               |                            |                | Total depth drilled was 188.0 feet.                                                                                                                                                    |
| 190            |             |             |               |                            |                |                                                                                                                                                                                        |
| 195            |             |             |               |                            |                |                                                                                                                                                                                        |
| 200            |             |             |               |                            |                |                                                                                                                                                                                        |

File: 8370.LOG

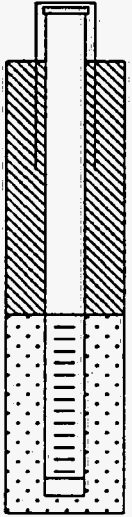
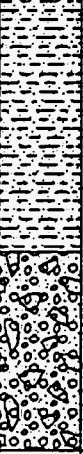
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# **MONITORING WELL COMPLETION LOG 88-85**

|                                                     |                                     |                                    |
|-----------------------------------------------------|-------------------------------------|------------------------------------|
| Project: Monticello Mill Tailings Site              | North Coordinate (ft.): 10,336.2    | Date Drilled: 09/30/88             |
| Location: Monticello, Utah                          | East Coordinate (ft.): 23,982.7     | Drilling Method: Hollow-Stem Auger |
| Site: Downgradient, just east of East Tailings Pile | Ground Elevation (ft. MSL): 6797.1  | Sampling Method: Split Barrel      |
| Total Depth (ft.): 12.5                             | Measuring Point Elev. (ft.): 6797.6 | Development Date: Unknown          |
| Auger Stem Size (in.): Unknown                      | Auger Head Size (in.): Unknown      | Water Level (ft. BGL): Unknown     |

|                                  |                       |                                   |
|----------------------------------|-----------------------|-----------------------------------|
| <b>WELL INSTALLATION</b>         | <b>INTERVAL (ft.)</b> | <b>BIT SIZES (in.)</b>            |
| Blank Casing: 2.0 in. SCH 40 PVC | +0.5 to 6.5           | Not Applicable                    |
| Screen: 2.0 in. SCH 40 PVC       | 6.5 to 11.5           |                                   |
| Slot Size: 0.02 in.              |                       |                                   |
| End Cap: 2.0 in. SCH 40 PVC      | 11.5 to 12.0          | <b>SURFACE CASING (ft.)</b>       |
| Grout: Unknown                   | 0.0 to 6.5            | Protective Steel from +1.6 to 1.0 |
| Sealant: NA                      |                       |                                   |
| Sand Pack (U): Unknown           | 6.5 to 12.5           |                                   |
| Sand Pack (L): NA                |                       | Comments: Locking cap.            |

| Depth (ft.)            | Blows/ft - in. | Sample Int. | Sample No. | Well Completion Diagram                                                            | Graphic Log                                                                        | Description                                                                |
|------------------------|----------------|-------------|------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|----------------------------------------------------------------------------|
|                        |                |             |            |                                                                                    |                                                                                    | Logged By: M. Kautsky                                                      |
| 5                      | 18-21<br>15    | X           |            |  |  | SANDY SILT, ML, brown (7.5YR 4/2), dry to slightly moist, dense.           |
| 10                     | 50<br>50       | X           |            |                                                                                    |                                                                                    | 8.0 SANDY GRAVEL, GP, brown (7.5YR 4/2), coarse grained, dense, saturated. |
| 100/4"                 |                | X           |            |                                                                                    |                                                                                    | 12.5 DAKOTA SANDSTONE.                                                     |
| 15                     |                |             |            |                                                                                    |                                                                                    | Total depth drilled was 12.5 feet.                                         |
| 20                     |                |             |            |                                                                                    |                                                                                    |                                                                            |
| 25                     |                |             |            |                                                                                    |                                                                                    |                                                                            |
| File: 8885.LOG         |                |             |            |                                                                                    |                                                                                    | Page 1 of 1                                                                |
| Date Drawn: 03/02/1994 |                |             |            |                                                                                    |                                                                                    |                                                                            |

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# MONITORING WELL COMPLETION LOG 92-05

Project: Monticello Mill Tailings Site  
 Location: Monticello, Utah  
 Site: Upgradient, just west of U.S. Highway 191  
 Total Depth (ft.): 16.83  
 Auger Stem Size (in.): 4.5 ID X 7.625 OD

North Coordinate (ft.): 8,818.8  
 East Coordinate (ft.): 19,863.1  
 Ground Elevation (ft. MSL): 6891.9  
 Measuring Point Elev. (ft.): 6894.78  
 Auger Head Size (in.): 8.0

Date Drilled: 09/20/92  
 Drilling Method: Hollow-Stem Auger  
 Sampling Method: Split Barrel, 3.0 in X 24 in.  
 Development Date: 10/08/92 - 10/28/92  
 Water Level (ft. BGL): 14.9, 09/20/92

**WELL INSTALLATION**

Blank Casing: 2.0 in. TriLok Sch 40 PVC  
 Screen: 2.0 in. TriLok Sch 40 PVC  
 Slot Size: 0.010 in.  
 End Cap: 2.0 in. TriLok SCH 40 PVC  
 Grout: NA  
 Sealant: 1/4 in. Enviroplug Pellets  
 Sand Pack (U): #20-40 Silica Sand  
 Sand Pack (L): #10-20 Silica Sand

**INTERVAL (ft.)**

+2.88 to 11.45  
 11.45 to 16.36  
 16.36 to 16.83  
 3.0 to 8.5  
 8.5 to 9.2  
 8.5 to 16.83

**BIT SIZES (in.)**

Not Applicable

**SURFACE CASING (ft.)**

4.0 in. Protective Steel from +3.26 to 1.74  
 Cement Pad from +0.31 to 3.0

Comments: CME-75 Drill Rig

| Depth (ft.) | Blows/8-in. | Sample Int. | Sample No. | Well Completion Diagram | Graphic Log | Description                                                                                                                                                                                                    |
|-------------|-------------|-------------|------------|-------------------------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |             |             |            |                         |             | Logged By: D. Traub                                                                                                                                                                                            |
| 5-7         | X           |             | soil       |                         |             | SILT, dark grayish brown (10YR 4/2), moist to 0.15 feet, then dry, no pebbles. 1.0 feet - white calcareous (strong reaction to HCL) material along fissures and in root holes.                                 |
| 10-10       | X           |             | samples    |                         |             |                                                                                                                                                                                                                |
| 6-8         | X           |             | not        |                         |             | 3.0 Slightly lighter color than above, grayish brown (10YR 5/2), less than 1% oxidized black organic material, very dry.                                                                                       |
| 6-7         | X           |             | saved      |                         |             |                                                                                                                                                                                                                |
| 3-3         | X           |             |            |                         |             | 4.9 Moist, darker due to moisture, slightly clayey (4.9-6.0 feet), low plasticity, 3% black organic material.                                                                                                  |
| 5-7         | X           |             |            |                         |             | 5.8 Very moist, water droplets on sampler.                                                                                                                                                                     |
| 2-3         | X           |             |            |                         |             | 6.0 Dark brown (10YR 3/3).                                                                                                                                                                                     |
| 9-10        | X           |             |            |                         |             | 7.8 SILTY SAND, mottled color (mainly orange-brown), slightly clayey, 15% rounded igneous pebbles to 3/4 in. A 2 in. fractured pebble at 7.8 feet. Less silt below 7.8 feet. Low plasticity from 6.0-7.8 feet. |
| 8-12        | X           |             |            |                         |             |                                                                                                                                                                                                                |
| 25-30       | X           |             |            |                         |             | 8.8 SILTY, SANDY GRAVEL, less fines than at 6.0 to 8.0 feet, 70% pebbles to 3/4 in., 20% coarse-grained sand, subrounded to subangular pebbles to 2 1/2 in. Cobble stuck in sampler shoe.                      |
| 5-18        | X           |             |            |                         |             |                                                                                                                                                                                                                |
| 25-22       | X           |             |            |                         |             | 10.0 SILTY SAND, dark grayish brown (10YR 4/2), slightly clayey, low plasticity, 40% igneous pebbles to 1 1/2 in. Fractured pieces of igneous and sandstone cobbles with some rounded to subrounded edges.     |
| 19-26       | X           |             |            |                         |             |                                                                                                                                                                                                                |
| 40-38       | X           |             |            |                         |             | 11.0 SANDY GRAVEL, dark brown, minor clay, moist, 25% fine-grained sand, rounded igneous and sandstone pebbles to 3.0 in.                                                                                      |
| 14-19       | X           |             |            |                         |             | Saturated at 14.9 feet.                                                                                                                                                                                        |
| 23-30       | X           |             |            |                         |             | 15.8 DAKOTA SANDSTONE, SILTY SAND/SANDSTONE??, very dark gray (10YR 3/1), silty, some horizontal bedding, strong reaction to HCL, scattered fossil fragments, no pebbles.                                      |
| 47/6"       | X           |             |            |                         |             | Total depth drilled was 16.83 feet.<br>Lithology for the first 10 feet of hole was taken from a hole drilled about 10 feet to the east and abandoned.                                                          |

File: 9205.LOG

Date Drawn: 02/04/1994

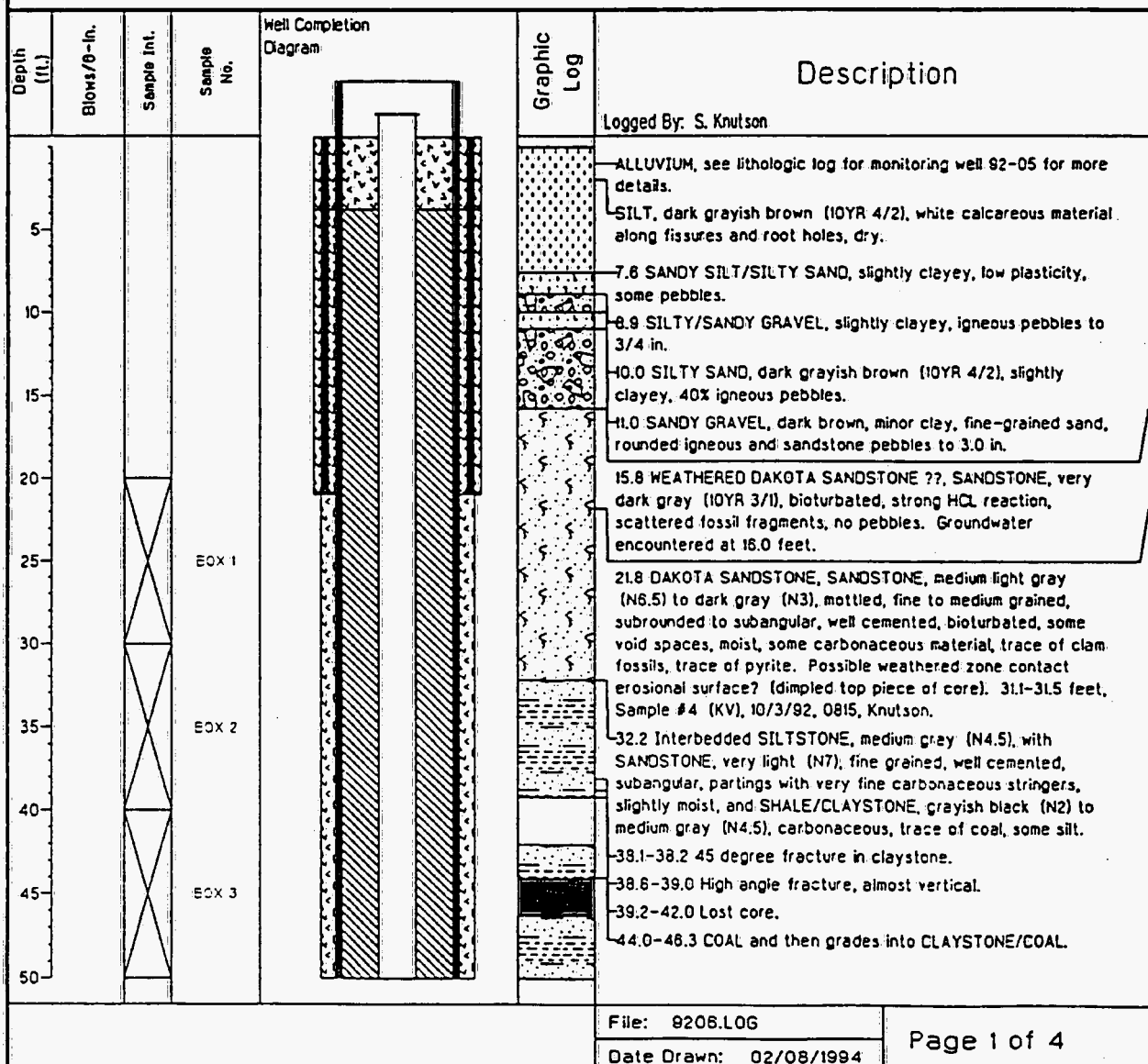
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# **MONITORING WELL COMPLETION LOG 92-06**

|                                                 |                                      |                                        |
|-------------------------------------------------|--------------------------------------|----------------------------------------|
| Project: Monticello Mill Tailings Site          | North Coordinate (ft.): 9847.7       | Date Drilled: 09/22/92 - 10/16/92      |
| Location: Monticello, Utah                      | East Coordinate (ft.): 19,859.8      | Drilling Method: Air Rotary/Core       |
| Site: Upgradient, just west of U.S. Highway 191 | Ground Elevation (ft. MSL): 6892.6   | Sampling Method: NX Core               |
| Total Depth (ft.): 160.0                        | Measuring Point Elev. (ft.): 6894.95 | Development Date: 11/08/92 - 11/09/92  |
| Auger Stem Size (in.): NA                       | Auger Head Size (in.): NA            | Water Level (ft. BGL): 109.6, 10/16/92 |

|                                         |                       |                                                         |
|-----------------------------------------|-----------------------|---------------------------------------------------------|
| <b>WELL INSTALLATION</b>                | <b>INTERVAL (ft.)</b> | <b>BIT SIZES (in.)</b>                                  |
| Blank Casing: 4.0 in. Trilok SCH 40 PVC | 2.35 to 129.4         | 17.5 in. Rotary from 0.0 to 21.0                        |
| Screen: 4.0 in. Trilok SCH 40 PVC       | 129.4 to 159.4        | 12.25 in. Rotary from 21.0 to 120.0                     |
| Slot Size: 0.010 in.                    |                       | 7.88 in. Rotary from 120.0 to 160.0                     |
| End Cap: 4.0 in. Trilok SCH 40 PVC      | 159.4 to 160.0        | <b>SURFACE CASING (ft.)</b>                             |
| Grout: Enviroplug Grout                 | 3.8 to 123.0          | 14.0 in. Steel from 0.0 to 21.0                         |
| Sealant: 1/4 in. Bentonite Pellets      | 123.0 to 126.0        | 8.625 in. Steel from +2.64 to 120.0                     |
| Sand Pack (U): #20-40 Silica Sand       | 126.0 to 160.0        | Cement Pad from +0.27 to 3.0                            |
| Sand Pack (L): NA                       |                       | Comments: A locking cap was welded to the steel casing. |



# MONITORING WELL COMPLETION LOG 92-06

| Depth<br>(Ft.) | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                                         |
|----------------|-------------|-------------|---------------|----------------------------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 55             |             |             | BOX 4         |                            |                | 50.5 SILTSTONE, carbonaceous, trace pyrite, some COAL intervals.                                                                                                                                                    |
|                |             |             |               |                            |                | 53.1 COAL, 1% pyrite, trace of calcium stringers, strong HCL reaction, vertical fracture (53.1-53.6 feet).                                                                                                          |
|                |             |             |               |                            |                | 53.8 Interbedded SANDSTONE, medium light gray (N8), fine grained, well cemented, bioturbated, carbonaceous, CLAYSTONE, medium gray (N4.5) to medium dark gray (N4), carbonaceous, with SILTSTONE, medium gray (N5). |
| 60             |             |             |               |                            |                | 55.0-56.4 Lost core.                                                                                                                                                                                                |
|                |             |             |               |                            |                | 60.0-61.8 Lost core.                                                                                                                                                                                                |
| 65             |             |             | BOX 5         |                            |                | 63.9-64.3 45 degree fracture, no infilling.                                                                                                                                                                         |
| 70             |             |             |               |                            |                | 70.1 CLAYSTONE, silty medium dark gray (N4). 70.8 feet, SILTSTONE.                                                                                                                                                  |
|                |             |             |               |                            |                | 70.8 SILTSTONE, medium gray (N5).                                                                                                                                                                                   |
| 75             |             |             | BOX 6         |                            |                | 73.8 SANDSTONE, medium light gray (N8), very fine grained, trace carbonaceous material and pyrite.                                                                                                                  |
|                |             |             |               |                            |                | 77.0 SANDSTONE, fine grained, bioturbated, wavy bedding.                                                                                                                                                            |
| 80             |             |             |               |                            |                | 78.8 Several thin calcareous layers in sandstone intervals.                                                                                                                                                         |
|                |             |             |               |                            |                | 81.1-82.7 SANDSTONE, very light gray (N8) to light gray (N7), fine to medium grained, some carbonaceous material, reworked zone, fossil fragments, trace pyrite, trace sandstone fragments.                         |
| 85             |             |             | BOX 7         |                            |                | 81.5-82.1 Hairline fractures with calcareous fracture infilling (1 mm).                                                                                                                                             |
|                |             |             |               |                            |                | 83.4-83.6 45 degree fracture, no infilling.                                                                                                                                                                         |
|                |             |             |               |                            |                | 84.65-84.7 45 degree fracture, slickensides, no infill.                                                                                                                                                             |
| 90             |             |             |               |                            |                | 84.75 Horizontal fracture (2 mm gypsum infill), medium dark gray (N4).                                                                                                                                              |
|                |             |             |               |                            |                | 85.1-85.5 45 degree fracture zone, slickensides (1 mm opening, no filling).                                                                                                                                         |
|                |             |             |               |                            |                | 88.35-88.75 Fractured zone, 45 degree, horizontal with clay infill and gypsum.                                                                                                                                      |
| 95             |             |             | BOX 8         |                            |                | 90.0-90.4 Lost core.                                                                                                                                                                                                |
|                |             |             |               |                            |                | 90.4 CLAYSTONE, silty, medium gray (N6.5).                                                                                                                                                                          |
|                |             |             |               |                            |                | 94.3-94.7 Lost core.                                                                                                                                                                                                |
| 100            |             |             |               |                            |                | 95.2-95.8 Fracture zone, vertical, horizontal, and 45 degrees                                                                                                                                                       |

File: 9206.LOG

Date Drawn: 02/08/1994

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MONITORING WELL COMPLETION LOG 92-06

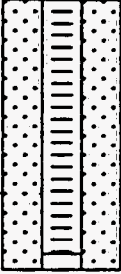
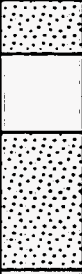
| Depth<br>(ft.) | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                                                                                                                            |
|----------------|-------------|-------------|---------------|----------------------------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                        |
| 100.0          |             |             |               |                            |                | 100.0 COAL, 3 mm layer.                                                                                                                                                                                                                                                                                |
| 100.3          |             |             |               |                            |                | 100.3 SANDSTONE, light gray (N7) to dark gray (N3), mottled, fine to medium grained, well cemented, very thin carbonaceous layers, subrounded to subangular pieces. At 103.9 feet, well cemented, some thin layers of pale- yellowish broken sandstone (2-4 mm), trace coal fragments, slightly moist. |
| 104.0-104.5    |             |             |               |                            |                | 104.0-104.5 Sample #5 (KV), 10/05/92, 1550, Knutson.                                                                                                                                                                                                                                                   |
| 105.7-106.0    |             |             |               |                            |                | 105.7-106.0 Vertical fracture, no infilling.                                                                                                                                                                                                                                                           |
| 107.8          |             |             |               |                            |                | 107.8 Green claystone clasts.                                                                                                                                                                                                                                                                          |
| 109.5-109.85   |             |             |               |                            |                | 109.5-109.85 Incomplete vertical fracture, very slightly calcareous.                                                                                                                                                                                                                                   |
| 110-115.4      |             |             |               |                            |                | 110-115.4 SANDSTONE, light olive brown (5Y 5/6), medium grained, iron oxide staining on some grains.                                                                                                                                                                                                   |
| 111.7- 118.65  |             |             |               |                            |                | 111.7- 118.65 Some chert fragment layers and trace of green claystone clasts.                                                                                                                                                                                                                          |
| 118.65         |             |             |               |                            |                | 118.65 SANDSTONE, pale yellowish brown (10YR 6/2), medium grained, subangular to subrounded, very thin layers of carbonaceous material, conglomeratic, chert and sandstone clasts from 1-3 mm, irregular shapes (black to gray), crumbly grains on outside of core.                                    |
| 118.0          |             |             |               |                            |                | 118.0 BURRO CANYON FORMATION, SANDSTONE, very light gray (N8), very fine grained, no carbonaceous material.                                                                                                                                                                                            |
| 119.5-119.8    |             |             |               |                            |                | 119.5-119.8 Color becomes pinkish gray (5YR 8/1).                                                                                                                                                                                                                                                      |
| 120.0-121.0    |             |             |               |                            |                | 120.0-121.0 Interval not cored.                                                                                                                                                                                                                                                                        |
| 121.0          |             |             |               |                            |                | 121.0 SILTY SANDSTONE, light greenish gray (5G8/1), very fine to fine grained, medium cemented but soft to blade, some interbedded layers of CLAYSTONE/SILTSTONE, greenish gray (5G 8/1), becomes well cemented at 126.0 feet, some pyrite.                                                            |
| 129.4-130.1    |             |             |               |                            |                | 129.4-130.1 Lost core.                                                                                                                                                                                                                                                                                 |
| 130.1          |             |             |               |                            |                | 130.1 SANDSTONE, color becomes very light gray (N8) to light gray (N7), fine grained, well cemented, slightly moist, pyrite up to 2%.                                                                                                                                                                  |
| 132.5          |             |             |               |                            |                | 132.5 Green CLAYSTONE clasts (up to 1 in.) in SANDSTONE.                                                                                                                                                                                                                                               |
| 136.9-137.3    |             |             |               |                            |                | 136.9-137.3 Sample #8 (KV), 10/15/92, 1400, Knutson.                                                                                                                                                                                                                                                   |
| 138.15         |             |             |               |                            |                | 138.15 5% fracture, no infill; grades into SANDSTONE, medium grained.                                                                                                                                                                                                                                  |
| 138.35         |             |             |               |                            |                | 138.35 Interbedded thin layers of mafic minerals/pebbles; black chert, gray sandstone fragments, feldspars, green claystone clasts.                                                                                                                                                                    |
| 138.65-139.6   |             |             |               |                            |                | 138.65-139.6 Fracture zone, horizontal and almost vertical, no infill.                                                                                                                                                                                                                                 |
| 143.75         |             |             |               |                            |                | 143.75 Rock fragments, then grades into SANDSTONE, CONGLOMERATIC, medium grained.                                                                                                                                                                                                                      |
| 144.8-145.0    |             |             |               |                            |                | 144.8-145.0, 45 degree fracture.                                                                                                                                                                                                                                                                       |
| 145.0          |             |             |               |                            |                | 145.0 SANDSTONE, white (N9.5), very fine grained, well cemented (almost silicified), two - 45 degree fractures, incomplete. Thin graded layers of chert and sandstone pebbles/fragments (dipping 45 degrees).                                                                                          |

File: 9206.LOG

Date Drawn: 02/08/1994

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# MONITORING WELL COMPLETION LOG 92-06

| Depth<br>(ft.) | Blows/ft.-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                        | Graphic<br>Log                                                                    | Description                                                                                                                                                                                                    |
|----------------|---------------|-------------|---------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                |               |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                |
| 155            |               | X           | BOX 14        |  |  | (continued) some clasts of green claystone. Color becomes light gray (N7) at 148.7 feet. Sample #9 (KV), 148.0-148.35 feet, 10/15/92, 1800, Knutson. 147.5-149.6 Fracture zone, 45 degree fracture, no infill. |
| 160            |               |             |               |                                                                                   |                                                                                   | 150.2 SANDSTONE, light gray (N7) to greenish gray (SGY 8/1), fine to medium grained, well cemented, trace to some chert and pyrite.                                                                            |
| 165            |               |             |               |                                                                                   |                                                                                   | 150.6-152.0 Fracture zone, vertical, broken up interval.                                                                                                                                                       |
| 170            |               |             |               |                                                                                   |                                                                                   | 152.0-154.8 Lost core, very soft zone when drilling.                                                                                                                                                           |
| 175            |               |             |               |                                                                                   |                                                                                   | 154.8 SANDSTONE, light greenish gray (SG 8/1), fine grained, well cemented.                                                                                                                                    |
| 180            |               |             |               |                                                                                   |                                                                                   | 158.0 Color becomes very light gray (N8.5), trace pyrite.                                                                                                                                                      |
| 185            |               |             |               |                                                                                   |                                                                                   | 158.6-180.0 Incomplete vertical fracture with sandstone, chert, and plagioclase fragments in thin layers.                                                                                                      |
| 190            |               |             |               |                                                                                   |                                                                                   | Total depth drilled was 180.0 feet.                                                                                                                                                                            |
| 195            |               |             |               |                                                                                   |                                                                                   | Stainless steel stabilizers were placed at 124.0, 80.0, and 10.0 feet.                                                                                                                                         |
| 200            |               |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                |

File: 9206.LOG

Date Drawn: 02/08/1994

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MONITORING WELL COMPLETION LOG 92-07

|                                                     |                                      |                                                 |
|-----------------------------------------------------|--------------------------------------|-------------------------------------------------|
| Project: Monticello Mill Tailings Site              | North Coordinate (ft.): 10,162.3     | Date Drilled: 10/02/92                          |
| Location: Monticello, Utah                          | East Coordinate (ft.): 23,918.2      | Drilling Method: Hollow-Stem Auger              |
| Site: Downgradient, just east of East Tailings Pile | Ground Elevation (ft. MSL): 6803.6   | Sampling Method: Split Barrel, 3.0 in. X 24 in. |
| Total Depth (ft.): 21.33                            | Measuring Point Elev. (ft.): 6805.85 | Development Date: 10/17/92                      |
| Auger Stem Size (in.): 4.5 ID X 7.625 OD            | Auger Head Size (in.): 8.0           | Water Level (ft. BGL): 16.86, 10/18/92          |

|                | WELL INSTALLATION          | INTERVAL (ft.) |
|----------------|----------------------------|----------------|
| Blank Casing:  | 2.0 in. TriLok Sch 40 PVC  | +225 to 15.3   |
| Screen:        | 2.0 in. TriLok Sch 40 PVC  | 15.3 to 20.3   |
| Slot Size:     | 0.010 in.                  |                |
| End Cap:       | 2.0 in. TriLok Sch 40 PVC  | 20.3 to 20.7   |
| Grout:         | Enviroplug                 | 2.0 to 9.5     |
| Sealant:       | 1/4 in. Enviroplug Pellets | 9.5 to 12.6    |
| Sand Pack (U): | #20-40 Silica Sand         | 12.6 to 13.0   |
| Sand Pack (L): | #10-20 Silica Sand         | 13.0 to 21.3   |

BIT SIZES (in)  
Not Applicable

**SURFACE CASING (ft)**  
**4.0 in. Protective Steel from +2.57 to 2.43**  
**Cement Pad from +0.37 to 2.0**

Comments: CME-75 Drill Rig

|                |             |             |               | Well Completion<br>Diagram | Graphic<br>Log                                                                                    | Description                                                                                                                                                     |
|----------------|-------------|-------------|---------------|----------------------------|---------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Depth<br>(ft.) | Blows/6-in. | Sample Int. | Sample<br>No. |                            |                                                                                                   | Logged By: D. Traub                                                                                                                                             |
| 5/6            |             | X           | soil          |                            |                                                                                                   | SANDY SILT/SILTY SAND, dark brown (7.5YR 4/3), dry, stiff, roots throughout, moderate HCL reaction.                                                             |
| 7/9            |             | X           | samples       |                            |                                                                                                   | 2.0 Not as stiff as above, firm, 5% caliche on fractures, strong reaction to HCL, dry.                                                                          |
| 7/11           |             | X           | not           |                            |                                                                                                   |                                                                                                                                                                 |
| 13/12          |             | X           | saved         |                            |                                                                                                   |                                                                                                                                                                 |
| 5              |             | X           |               |                            |                                                                                                   | 5.0 Same as above, dark brown (7.5YR 4/3).                                                                                                                      |
| 9/10           |             | X           |               |                            |                                                                                                   | 6.0 Dark brown (7.5YR 3/2), stiff, 2% caliche, 1% black oxidized organic material to 1/4 in., slightly moist.                                                   |
| 9/9            |             | X           |               |                            |                                                                                                   |                                                                                                                                                                 |
| 7/8            |             | X           |               |                            |                                                                                                   |                                                                                                                                                                 |
| 9/11           |             | X           |               |                            |                                                                                                   |                                                                                                                                                                 |
| 7/6            |             | X           |               |                            |                                                                                                   |                                                                                                                                                                 |
| 10             |             | X           |               |                            |                                                                                                   | Little caliche below 9.0 feet, moderate HCL reaction down to 9.6 feet then no HCL reaction, moist at 9.6 feet.                                                  |
| 6/6            |             | X           |               |                            |                                                                                                   | 10.0 SILTY SAND/SANDY SILT, dark brown, very fine-grained sand, no caliche.                                                                                     |
| 3/5            |             | X           |               |                            |                                                                                                   |                                                                                                                                                                 |
| 10/10          |             | X           |               |                            |                                                                                                   | 11.1 SANDY/SILTY GRAVEL, dark brown (7.5YR 4/4), subrounded to subangular, igneous pebbles to 1 in., very silty at 11.9 feet.                                   |
| 3/5            |             | X           |               |                            |                                                                                                   |                                                                                                                                                                 |
| 8/21           |             | X           |               |                            |                                                                                                   | 12.0 SILTY SAND, dark brown (10YR 2/2), very fine-grained, firm, moist, few pebbles to 13.8 feet, then 20% igneous pebbles subrounded, very weathered.          |
| 15             |             | X           |               |                            |                                                                                                   |                                                                                                                                                                 |
| 13/13          |             | X           |               |                            |                                                                                                   | 14.0 SANDY/SILTY GRAVEL, subrounded igneous pebbles to 3 in., very wet at 15.8 feet, but not saturated, 10% fractured cobbles, very silty from 15.7 to 16 feet. |
| 6/10           |             | X           |               |                            |                                                                                                   | Sampler refusal at 17.0 feet, saturated at 16.5 feet.                                                                                                           |
| 16/40          |             | X           |               |                            |                                                                                                   | 18.0 SANDY/SILTY GRAVEL, dark brown, fractured igneous pebbles and subrounded igneous pebbles to 1 1/2 in.                                                      |
| refusal        |             | X           |               |                            |                                                                                                   |                                                                                                                                                                 |
| 26/28          |             | X           |               |                            | 20.3 DAKOTA SANDSTONE, SILTSTONE, dark gray. Sampler refusal at 20.9 feet. Augered to 21.33 feet. |                                                                                                                                                                 |
| 50-5"          |             | X           |               |                            | Total depth drilled was 21.33 feet.                                                               |                                                                                                                                                                 |
| 20             | 32/50-5     | X           |               |                            |                                                                                                   |                                                                                                                                                                 |
| 25             |             |             |               |                            |                                                                                                   |                                                                                                                                                                 |

|                        |             |
|------------------------|-------------|
| File: 9207.log         | Page 1 of 1 |
| Date Drawn: 02/04/1994 |             |

# MONITORING WELL COMPLETION LOG 92-08

Project: Monticello Mill Tailings Site  
Location: Monticello, Utah  
Site: Downgradient, north of Montezuma Creek  
Total Depth (ft.): 18.25  
Auger Stem Size (in.): 4.25 ID X 7.625 OD

|                              |           |
|------------------------------|-----------|
| North Coordinate (ft.):      | 9,612.43  |
| East Coordinate (ft.):       | 25,382.00 |
| Ground Elevation (ft. MSL):  | 6773.1    |
| Measuring Point Elev. (ft.): | 6775.68   |
| Auger Head Size (in.):       | 8.0       |

Date Drilled: 10/01/92  
Drilling Method: Hollow-Stem Auger  
Sampling Method: Split Barrel, 3.0 in. X 24 in.  
Development Date: 10/18/92 - 10/19/92  
Water Level (ft. BGL): 4.8, 10/01/92

## WELL INSTALLATION

|                |                            |
|----------------|----------------------------|
| Blank Casing:  | 2.0 in. TriLok SCH 40 PVC  |
| Screen:        | 2.0 in. TriLok SCH 40 PVC  |
| Slot Size:     | 0.010 in.                  |
| End Cap:       | 2.0 in. TriLok SCH 40 PVC  |
| Grout:         | Enviroplug                 |
| Sealant:       | 1/4 in. Enviroplug Pellets |
| Sand Pack (U): | #20-40 Silica Sand         |
| Sand Pack (L): | NA                         |

INTERVAL (ft)

+2.58 to 12.9

12.9 to 17.9

17.9 to 18.25

2.9 to 7.2

7.2 to 10.4

10.4 to 18.25

### BIT SIZES (in)

**Not Applicable**

**SURFACE CASING (ft)**

**4.0 in. Protective Steel from +2.9 to 21**

**Cement Pad from +0.44 to 2.9**

Comments: CME-75 Drill Rig

| Depth<br>(ft.) | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                                                                           | Graphic<br>Log | Description                                                                                                                                        |  |
|----------------|-------------|-------------|---------------|--------------------------------------------------------------------------------------------------------------------------------------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------|--|
|                |             |             |               |                                                                                                                                      |                | Logged By: D. Traub                                                                                                                                |  |
| 2/4            | X           |             | soil          |                                                                                                                                      |                | SANDY SILT, dark brown (7.5YR 3/3), soft, dry, no caliche, no reaction with HCL, trace of roots.                                                   |  |
| 3/6            | X           |             | samples       |                                                                                                                                      |                | Slightly moist, fine-grained sand.                                                                                                                 |  |
| 4/3            | X           |             | not           |                                                                                                                                      |                |                                                                                                                                                    |  |
| 3/2            | X           |             | saved         |                                                                                                                                      |                |                                                                                                                                                    |  |
| 0/2            | X           |             |               |                                                                                                                                      |                | 4.0 Increase in moisture content, saturated at 4.8 feet, no pebbles, slightly clayey in several 0.1-0.2 foot thick intervals, very low plasticity. |  |
| 2/1            | X           |             |               |                                                                                                                                      |                | 6.0 Dark brown (7.5YR 3/2), saturated, soft, with minor intervals of low plasticity clay, no pebbles.                                              |  |
| push           | X           |             |               |                                                                                                                                      |                | 8.4 SAND, silty, clayey, almost sandy silt, dark brown, fine grained, saturated, more clay in 0.1 foot intervals.                                  |  |
| push           | X           |             |               |                                                                                                                                      |                | 10.8 0.2 foot layer of subrounded to subangular igneous pebbles.                                                                                   |  |
| 0/1            | X           |             |               |                                                                                                                                      |                |                                                                                                                                                    |  |
| 3/3            | X           |             |               |                                                                                                                                      |                |                                                                                                                                                    |  |
| 4/5            | X           |             |               |                                                                                                                                      |                |                                                                                                                                                    |  |
| 5/5            | X           |             |               |                                                                                                                                      |                |                                                                                                                                                    |  |
| 0/3            | X           |             |               |                                                                                                                                      |                |                                                                                                                                                    |  |
| 5/20           | X           |             |               |                                                                                                                                      |                |                                                                                                                                                    |  |
| 16/38          | X           |             |               |                                                                                                                                      |                | 13.8 GRAVEL, silty, sandy, with 30% subrounded igneous pebbles to 2 in., some iron staining, 20% fine-to medium- grained sand.                     |  |
| 35/48          | X           |             |               |                                                                                                                                      |                | 14.0 Igneous cobble stuck in sampler tip, mainly fractured igneous and sandstone (white) cobbles.                                                  |  |
| 25/28          | X           |             |               | 16.0 GRAVEL, gray to orange (iron-stained sand), fractured cobbles to 16.8 feet. Fractured igneous pebble gravel, gray to 17.9 feet. |                |                                                                                                                                                    |  |
| 32/40          | X           |             |               | 17.9 DAKOTA SANDSTONE, SILTSTONE, dark gray, Augered to 18.25 feet; hard drilling.                                                   |                |                                                                                                                                                    |  |
|                |             |             |               | Total depth drilled was 18.25 feet.                                                                                                  |                |                                                                                                                                                    |  |
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# MONITORING WELL COMPLETION LOG 92-09

Project: Monticello Mill Tailings Site  
Location: Monticello, Utah  
Site: Far downgradient, east of Millsite  
Total Depth (ft.): 16.4  
Auger Stem Size (in.): 4.5 ID X 7.625 OD

|                              |           |
|------------------------------|-----------|
| North Coordinate (ft.):      | 9,366.98  |
| East Coordinate (ft.):       | 27,449.65 |
| Ground Elevation (ft. MSL):  | 6730.8    |
| Measuring Point Elev. (ft.): | 6733.29   |
| Auger Head Size (in.):       | 8.0       |

Date Drilled: 09/24/92  
Drilling Method: Hollow-Stem Auger  
Sampling Method: Split Barrel, 3.0 in. X 24 in.  
Development Date: 10/08/92 - 10/20/92  
Water Level (ft. BGL): 11.69, 10/20/92

## WELL INSTALLATION

|                |                            |
|----------------|----------------------------|
| Blank Casing:  | 2.0 in. TriLok SCH 40 PVC  |
| Screen:        | 2.0 in. TriLok SCH 40 PVC  |
| Slot Size:     | 0.010 in.                  |
| End Cap:       | 2.0 in. TriLok SCH 40 PVC  |
| Grout:         | Enviroplug                 |
| Sealant:       | 1/4 in. Enviroplug Pellets |
| Sand Pack (U): | #20-40 Silica Sand         |
| Sand Pack (L): | #10-20 Silica Sand         |

## INTERVAL (FL)

+2.49 to 10.9  
10.9 to 16.0  
16.0 to 16.3  
2.0 to 4.25  
4.25 to 7.5  
7.5 to 8.0  
8.0 to 16.4

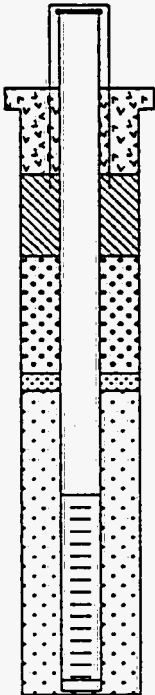
### BIT SIZES (in.)

**Not Applicable**

SURFACE CASING (FL)

4.0 in. Protective Steel from +2.79 to 2.21  
Cement Pad from +0.44 to 2.0

Comments: CME-75 Drill Rig

| Depth<br>(ft.) | Blows/8-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                                                                                          | Description                                                                                                                                                                                        |
|----------------|-------------|-------------|---------------|------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                |             |             |               |                                                                                    |                                                                                                                                                         | Logged By: D. Traub                                                                                                                                                                                |
| 1/8            | X           |             | soil          |  |                                                                                                                                                         | SILT, sandy, slightly clayey, dark brown (7.5YR 4/2), stiff, moist, no pebbles, some roots, minor caliche at 2.0 feet.                                                                             |
| 7/7            | X           |             | samples       |                                                                                    |                                                                                                                                                         |                                                                                                                                                                                                    |
| 4/5            | X           |             | not           |                                                                                    |                                                                                                                                                         |                                                                                                                                                                                                    |
| 5/6            | X           |             | saved         |                                                                                    |                                                                                                                                                         |                                                                                                                                                                                                    |
| 3/5            | X           |             |               |                                                                                    |                                                                                                                                                         | 4.3 Increase in moisture.                                                                                                                                                                          |
| 5/7            | X           |             |               |                                                                                    |                                                                                                                                                         | Slightly more clay from 6.5 to 6.8 feet, (no change in appearance but more plastic than before), no caliche 6 to 8 feet, minor reaction to HCL from 6.0 to 6.4 feet, then no reaction.             |
| 3/5            | X           |             |               |                                                                                    |                                                                                                                                                         |                                                                                                                                                                                                    |
| 7/8            | X           |             |               |                                                                                    |                                                                                                                                                         |                                                                                                                                                                                                    |
| 4/4            | X           |             |               |                                                                                    |                                                                                                                                                         |                                                                                                                                                                                                    |
| 5/10           | X           |             |               |                                                                                    |                                                                                                                                                         | 8.0 SILT, dark brown, one 3 in. subrounded igneous cobble at 8.4 feet.                                                                                                                             |
| 17/25          | X           |             |               |                                                                                    |                                                                                                                                                         | 8.8 SILT, sandy, black, saturated, 1 in. of gravel at 9.2 feet, abundant wood/plant material from 9.3 to 10.0 feet.                                                                                |
| 25/27          | X           |             |               |                                                                                    |                                                                                                                                                         | 10.0 Fractured light gray sandstone fragments plugged the sampler.                                                                                                                                 |
| 2/22           | X           |             |               |                                                                                    |                                                                                                                                                         |                                                                                                                                                                                                    |
| 24/33          | X           |             |               |                                                                                    |                                                                                                                                                         | 12.0 SAND, silty, dark gray, very wet, some light gray sandstone fragments to 3 in., 0.1 foot of rounded igneous pebble gravel between the sandstone fragments. Only 0.5 foot of sample recovered. |
| 0/0            | X           |             |               |                                                                                    |                                                                                                                                                         |                                                                                                                                                                                                    |
| 17/14          | X           |             |               |                                                                                    |                                                                                                                                                         | 14.0 No recovery, rock plugged sampler tip.                                                                                                                                                        |
| 50/5"          | X           |             |               |                                                                                    | 15.9 BURRO CANYON FORMATION, SILTSTONE, gray/green and some sandstone fragments, light gray. Sampler refusal after 0.5 foot. Very hard drilling, solid. |                                                                                                                                                                                                    |
|                |             |             |               |                                                                                    |                                                                                                                                                         | Total depth drilled was 16.4 feet.                                                                                                                                                                 |
|                |             |             |               |                                                                                    |                                                                                                                                                         |                                                                                                                                                                                                    |
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# MONITORING WELL COMPLETION LOG 92-10

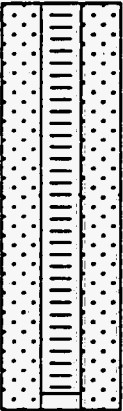

|                                          |                                     |                                       |
|------------------------------------------|-------------------------------------|---------------------------------------|
| Project: Monticello Mill Tailings Site   | North Coordinate (ft.): 9365.0      | Date Drilled: 10/02/92 - 10/26/92     |
| Location: Monticello, Utah               | East Coordinate (ft.): 27,424.8     | Drilling Method: Air/Mist Rotary      |
| Site: Far downgradient, east of Millsite | Ground Elevation (ft. MSL): 6731.5  | Sampling Method: NX Core              |
| Total Depth (ft.): 65.0                  | Measuring Point Elev. (ft.): 6733.8 | Development Date: 11/08/92            |
| Auger Stem Size (in.): NA                | Auger Head Size (in.): NA           | Water Level (ft. BGL): 31.0, 10/26/92 |

| WELL INSTALLATION                       | INTERVAL (ft.) | BIT SIZES (in.)                    |
|-----------------------------------------|----------------|------------------------------------|
| Blank Casing: 4.0 in. Trilok SCH 40 PVC | +2.3 to 34.4   | 12.25 in. Rotary from 0.0 to 25.0  |
| Screen: 4.0 in. Trilok SCH 40 PVC       | 34.4 to 64.4   | 7.88 in. Rotary from 25.0 to 60.0  |
| Slot Size: 0.010 in.                    |                |                                    |
| End Cap: 4.0 in. Trilok SCH 40 PVC      | 64.4 to 65.0   |                                    |
| Grout: Enviroplug Grout                 | 3.0 to 26.6    | SURFACE CASING (ft.)               |
| Sealant: 1/4 in. Bentonite Pellets      | 26.6 to 29.8   | 8.625 in. Steel from +2.38 to 25.0 |
| Sand Pack (U): #20-40 Silica Sand       | 29.8 to 65.0   | in. Cement Pad from +0.34 to 3.0   |
| Sand Pack (L): NA                       |                |                                    |

Comments: Locking cap was welded to steel casing.

| Depth<br>(ft.)         | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                                                                                                                                                       |
|------------------------|-------------|-------------|---------------|----------------------------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        |             |             |               |                            |                | Logged By: S. Knutson/C. Goodknight                                                                                                                                                                                                                                                                                               |
| 5                      |             |             |               |                            |                | ALLUVIUM - See lithologic log of monitoring well 92-09 for details.                                                                                                                                                                                                                                                               |
| 10                     |             |             |               |                            |                | SILT, sandy, clayey, dark brown (7.5YR 4/2), moist, stiff, no pebbles.                                                                                                                                                                                                                                                            |
| 15                     |             |             |               |                            |                | 10.0 GRAVEL, sandstone fragments, light gray.                                                                                                                                                                                                                                                                                     |
| 20                     |             |             |               |                            |                | 12.0 SAND, silty, dark gray, very wet, some sandstone fragments and igneous pebbles.                                                                                                                                                                                                                                              |
| 25                     |             |             |               |                            |                | 16.0 WEATHERED BURRO CANYON FORMATION (uppermost section ??), SANDSTONE, white to light tan, fine to medium grained.                                                                                                                                                                                                              |
| 30                     |             |             | BOX 1         |                            |                | 20.0 BURRO CANYON FORMATION, SANDSTONE, white to light tan, fine to medium grained, trace pyrite.                                                                                                                                                                                                                                 |
| 35                     |             |             |               |                            |                | 25.0 SILTSTONE, silicified, light green.                                                                                                                                                                                                                                                                                          |
| 40                     |             |             | BOX 2         |                            |                | 27.0 SANDSTONE, light gray (N7.5), fine grained, well cemented (almost silicified), subrounded to subangular grains, interbedded thin layers of mafic minerals/pebbles, conglomeratic, black to gray, layers dip - 10-20 degrees; chert, plagioclase, sandstone, pyrite, green claystone clasts, 1 m to 2 cm in size, very moist. |
| 45                     |             |             |               |                            |                | 30.6 Very thin layer of green claystone (1cm)                                                                                                                                                                                                                                                                                     |
| 50                     |             |             | BOX 3         |                            |                | 37.65 SANDSTONE, light gray (N7.5), fine grained.                                                                                                                                                                                                                                                                                 |
|                        |             |             |               |                            |                | 39.0-39.25 Sample #13 (KV), 10/25/92, 1315, Knutson                                                                                                                                                                                                                                                                               |
|                        |             |             |               |                            |                | 40.0 Samples above become more conglomeratic in separate layers.                                                                                                                                                                                                                                                                  |
|                        |             |             |               |                            |                | Note: After the 40.0-50.0 feet core run, borehole producing ~3 gpm of water.                                                                                                                                                                                                                                                      |
| File: 9210.LOG         |             |             |               |                            |                | Page 1 of 2                                                                                                                                                                                                                                                                                                                       |
| Date Drawn: 02/08/1994 |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                   |

# MONITORING WELL COMPLETION LOG 92-10

| Depth<br>(ft.)                                                                                                                                            | Blows/6-in. | Sample Int.                                            | Sample<br>No. | Well Completion<br>Diagram                                                        | Graphic<br>Log                                                                    | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|--------------------------------------------------------|---------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <div> <div>55</div> <div>60</div> <div>65</div> <div>70</div> <div>75</div> <div>80</div> <div>85</div> <div>90</div> <div>95</div> <div>100</div> </div> |             | <div> <div>55</div> <div>60</div> <div>65</div> </div> | BOX 4         |  |  | <p>50.4 SANDSTONE light gray (N7.5), fine grained, well cemented, subrounded to subangular grains, interbedded thin layers of mafic minerals/pebbles (~3% dip), trace green claystone clasts.</p> <p>51.35-51.65 Sample #14 (KV), 10/25/92, 1640, Knutson.</p> <p>54.5 Becomes conglomeratic with pebble and mafic minerals, plagioclase (size up to 2 cm), very thin green claystone layers.</p> <p>54.8 Color becomes pale yellowish brown (10YR 8/2), still conglomeratic; 55.1-55.3 feet - light gray, fine grained, pyrite at contact between siltstone.</p> <p>55.3 SILTY SANDSTONE, greenish gray (5G 6/1), very fine grained, well cemented, thin layers of claystone (greenish gray), slightly moist.</p> <p>57.5 Grades into sandstone, light gray, fine grained, well cemented, 1% pyrite.</p> <p>60.5 Interbedded thin layers of mafic minerals/pebbles, conglomeratic, size up to 4cm, ~45 degree dip, trace of green claystone clasts, moist.</p> <p>Total depth drilled was 65.0 feet.</p> <p>Stainless steel centralizer was placed at 29.0 feet.</p> |
|                                                                                                                                                           |             |                                                        |               |                                                                                   |                                                                                   | <div>File: 9210.LOG</div> <div>Date Drawn: 02/08/1994</div> <div>Page 2 of 2</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |



# MONITORING WELL COMPLETION LOG 92-11

Project: Monticello Mill Tailings Site North Coordinate (ft.): 10,618.07 Date Drilled: 10/01/92  
 Location: Monticello, Utah East Coordinate (ft.): 23,652.29 Drilling Method: Hollow-Stem Auger  
 Site: Downgradient, just east of East tailings Pile Ground Elevation (ft. MSL): 6806.5 Sampling Method: Split Barrel, 3.0 in. X 24 in.  
 Total Depth (ft.): 14.2 Measuring Point Elev. (ft.): 6808.93 Development Date: 10/09/92 - 10/20/92  
 Auger Stem Size (in.): 4.5 ID X 7.625 OD Auger Head Size (in.): 8.0 Water Level (ft. BGL): 12.33, 10/17/92

WELL INSTALLATION INTERVAL (ft.) BIT SIZES (in.)  
 Blank Casing: 2.0 in. TriLok SCH 40 PVC +2.43 to 9.53 Not Applicable  
 Screen: 2.0 in. TriLok SCH 40 PVC 9.53 to 13.88  
 Slot Size: 0.010 in.  
 End Cap: 2.0 in. TriLok SCH 40 PVC 13.88 to 14.18  
 Grout: Cement 0.0 to 4.0 SURFACE CASING (ft.)  
 Sealant: 1/4 in. Enviroplug Pellets 4.0 to 7.0 4.0 in. Protective Steel from +2.7 to 2.3  
 Sand Pack (U): #10-20 Silica Sand 7.0 to 14.18 Cement Pad from +0.37 to 4.0  
 Sand Pack (L): NA  
 Comments: CME-75 Drill Rig

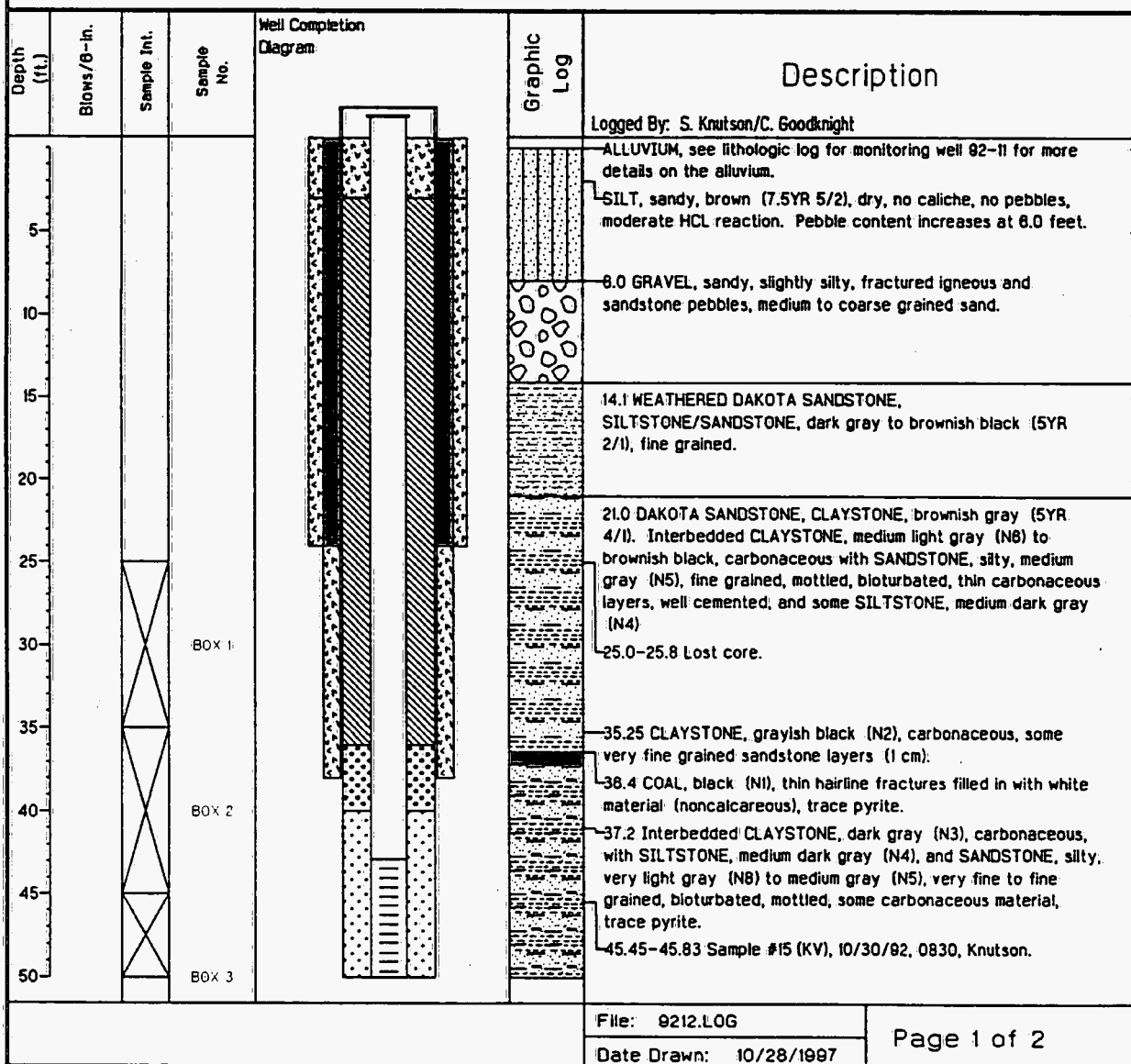
| Depth (ft.)            | Blows/8-in. | Sample Int. | Sample No. | Well Completion Diagram | Graphic Log | Description                                                                                                                                                                                                                     |
|------------------------|-------------|-------------|------------|-------------------------|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        |             |             |            |                         |             | Logged By: D. Traub                                                                                                                                                                                                             |
| 12/16                  |             |             | soil       |                         |             | SILT, sandy, brown (7.5YR 5/2), dry, no caliche or pebbles, moderate reaction to HCL.                                                                                                                                           |
| 10/14                  |             |             | samples    |                         |             |                                                                                                                                                                                                                                 |
| 2/3                    |             |             | not        |                         |             | 2.0 SILT, with very fine-grained sand, stiff, dry, slightly clayey, fine-to medium-grained sand content increasing.                                                                                                             |
| 4/6                    |             |             | saved      |                         |             | 4.6 SAND, silty, dark brown (7.5YR 4/2).                                                                                                                                                                                        |
| 6/8                    |             |             |            |                         |             | 6.0 SILT, sandy, dark brown, firm, moist, grades into a silty, medium-grained sand. 10% pebbles to 3/4 in. from 7.8 to 8.0 feet. Minor reaction to HCL throughout.                                                              |
| 7/9                    |             |             |            |                         |             | 8.0 GRAVEL, sandy, slightly silty, iron stained, various colors depending on pebble type (igneous or sandstone), fractured igneous and sandstone pebbles to 2 in. with 90% less than 1/4 in. Moist to 8.5 feet, then saturated. |
| 8/12                   |             |             |            |                         |             | Fractured, subrounded to subangular, igneous pebbles to 2 in., silty and sandy to 11.0 feet, then little silt from 11.0 to 12.0 feet.                                                                                           |
| 12/14                  |             |             |            |                         |             | GRAVEL, sandy, slightly silty, medium-to coarse-grained, slightly silty, subrounded to subangular igneous pebbles, 70% gravel, 25% sand, 5% silt.                                                                               |
| 9/20                   |             |             |            |                         |             | 14.1 DAKOTA SANDSTONE, SILTSTONE, dark gray, fragments on center bit, drilling hard, auger refusal                                                                                                                              |
| 22/26                  |             |             |            |                         |             | Total depth drilled was 14.2 feet.                                                                                                                                                                                              |
| 18/28                  |             |             |            |                         |             |                                                                                                                                                                                                                                 |
| 32/33                  |             |             |            |                         |             |                                                                                                                                                                                                                                 |
| 0/6                    |             |             |            |                         |             |                                                                                                                                                                                                                                 |
| 9/25                   |             |             |            |                         |             |                                                                                                                                                                                                                                 |
| 25/0"                  |             |             |            |                         |             |                                                                                                                                                                                                                                 |
| 15                     |             |             |            |                         |             |                                                                                                                                                                                                                                 |
| 20                     |             |             |            |                         |             |                                                                                                                                                                                                                                 |
| 25                     |             |             |            |                         |             |                                                                                                                                                                                                                                 |
| File: 9211.log         |             |             |            |                         |             | Page 1 of 1                                                                                                                                                                                                                     |
| Date Drawn: 02/07/1994 |             |             |            |                         |             |                                                                                                                                                                                                                                 |

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# **MONITORING WELL COMPLETION LOG 92-12**

|                                                     |                                     |                                      |
|-----------------------------------------------------|-------------------------------------|--------------------------------------|
| Project: Monticello Mill Tailings Site              | North Coordinate (ft.): 10622.4     | Date Drilled: 10/22/92 - 10/30/92    |
| Location: Monticello, Utah                          | East Coordinate (ft.): 23670.9      | Drilling Method: Mud/Air/Mist Rotary |
| Site: Downgradient, just east of East Tailings Pile | Ground Elevation (ft. MSL): 6807.1  | Sampling Method: NX Core             |
| Total Depth (ft.): 60.0                             | Measuring Point Elev. (ft.): 6809.4 | Development Date: NA                 |
| Auger Stem Size (in.): NA                           | Auger Head Size (in.): NA           | Water Level (ft. BGL): Dry, 10/30/92 |

|                                         |                       |                                                         |
|-----------------------------------------|-----------------------|---------------------------------------------------------|
| <b>WELL INSTALLATION</b>                | <b>INTERVAL (ft.)</b> | <b>BIT SIZES (in.)</b>                                  |
| Blank Casing: 4.0 in. Trilok SCH 40 PVC | +2.34 to 42.9         | 12.25 in. Rotary from 0.0 to 21.0                       |
| Screen: 4.0 in. Trilok SCH 40 PVC       | 42.9 to 52.9          | 7.88 in. Rotary from 21.0 to 60.0                       |
| Slot Size: 0.010 in.                    |                       |                                                         |
| End Cap: 4.0 in. Trilok SCH 40 PVC      | 52.9 to 53.5          | <b>SURFACE CASING (ft.)</b>                             |
| Grout: Enviroplug                       | 3.0 to 36.0           | 14.0 in. Steel from 0.0 to 24.0                         |
| Sealant: 1/4 in. Bentonite Pellets      | 36.0 to 40.0          | 8.625 in. Steel from +2.59 to 38.0                      |
| Sand Pack (U): #20-40 Silica Sand       | 40.0 to 54.9          | in. Cement Pad from +0.32 to 3.0                        |
| Sand Pack (L): NA                       |                       | Comments: A locking cap was welded to the steel casing. |



File: 9212.LOG

Date Drawn: 10/28/1997

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# MONITORING WELL COMPLETION LOG 92-12

| Depth<br>(Ft.) | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                                 |
|----------------|-------------|-------------|---------------|----------------------------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 55             |             |             |               |                            |                | 52.1-52.2 45 degree parting along COAL parting.                                                                                                                                                             |
|                |             |             |               |                            |                | 55.4 Decrease in carbonaceous material to 10%.                                                                                                                                                              |
| 60             |             |             |               |                            |                | 58.0 SANDSTONE, very light gray (N8), increase in grain size to fine to medium grained, trace of carbonaceous material, trace of pebbles/fragments, becoming slightly friable on outside of core.           |
|                |             |             |               |                            |                | 58.5 SANDSTONE, very light gray, fine to medium grained, well cemented, <1% mafic mineral/pebble fragments and carbonaceous fragments, 2% pebble fragments (3mm), white plagioclase?, fluvial crossbedding. |
| 65             |             |             |               |                            |                | Total depth drilled was 80.0 feet.                                                                                                                                                                          |
|                |             |             |               |                            |                | Stainless steel centralizers placed at 40.0 feet and 10.0 feet.                                                                                                                                             |
| 70             |             |             |               |                            |                | Bentonite pellets (1/4 in.) were placed in hole at 54.9-80.0 feet prior to well installation.                                                                                                               |
| 75             |             |             |               |                            |                |                                                                                                                                                                                                             |
| 80             |             |             |               |                            |                |                                                                                                                                                                                                             |
| 85             |             |             |               |                            |                |                                                                                                                                                                                                             |
| 90             |             |             |               |                            |                |                                                                                                                                                                                                             |
| 95             |             |             |               |                            |                |                                                                                                                                                                                                             |
| 100            |             |             |               |                            |                |                                                                                                                                                                                                             |

File: 9212.LOG

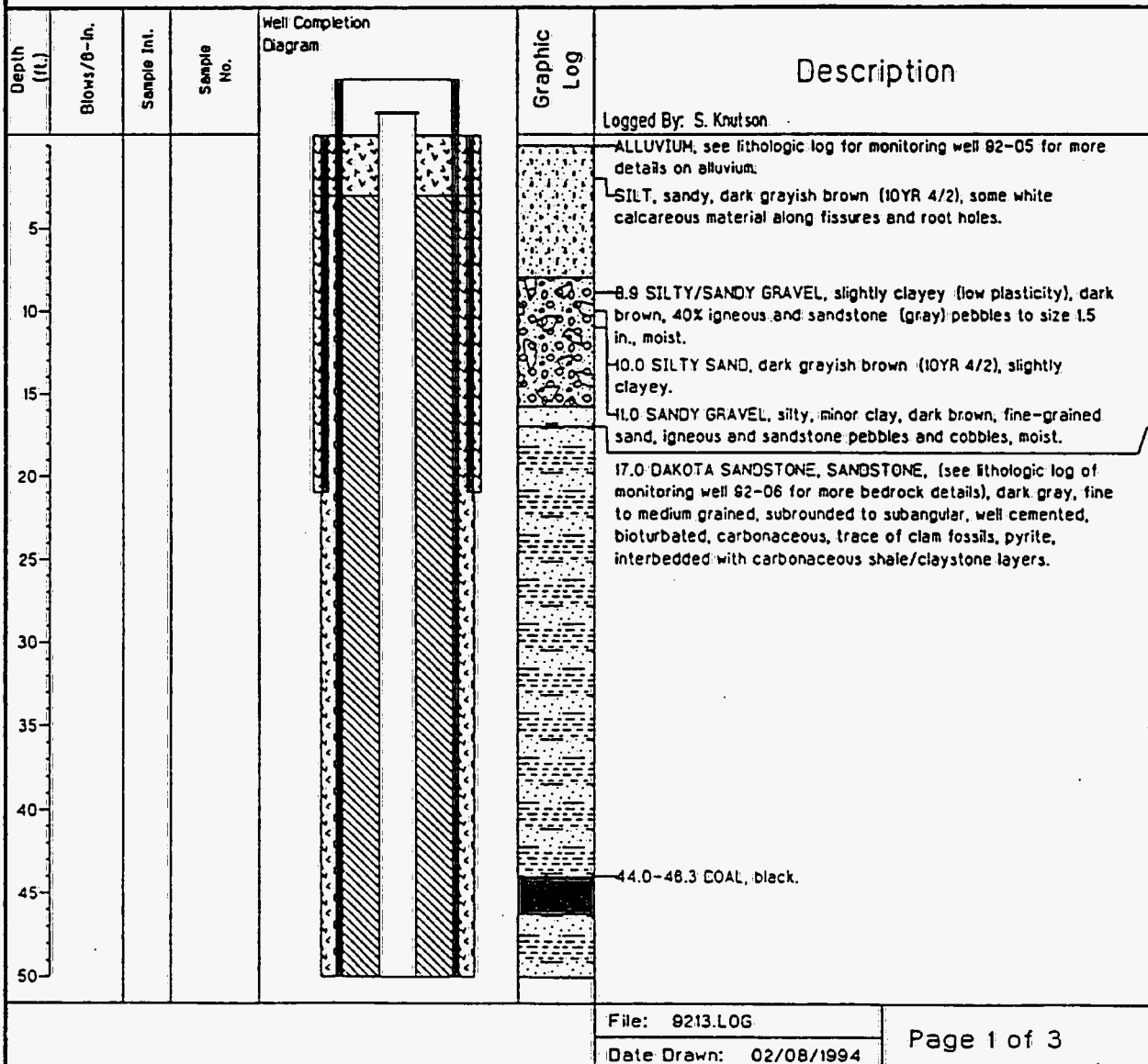
Date Drawn: 10/28/1997

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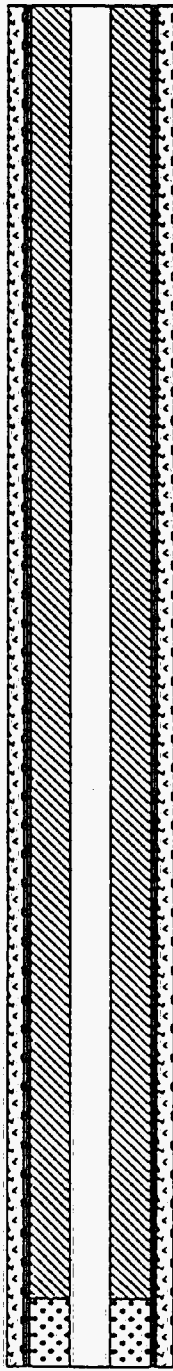

# MONITORING WELL COMPLETION LOG 92-13

|                                                 |                                     |                                        |
|-------------------------------------------------|-------------------------------------|----------------------------------------|
| Project: Monticello Mill Tailings Site          | North Coordinate (ft.): 9,853.2     | Date Drilled: 10/29/93                 |
| Location: Monticello, Utah                      | East Coordinate (ft.): 19,864.8     | Drilling Method: Air Rotary            |
| Site: Upgradient, just west of U.S. Highway 191 | Ground Elevation (ft. MSL): 6892.3  | Sampling Method: Rotary Cuttings       |
| Total Depth (ft.): 114.3                        | Measuring Point Elev. (ft.): 6894.7 | Development Date: 11/09/92             |
| Auger Stem Size (in.): NA                       | Auger Head Size (in.): NA           | Water Level (ft. BGL): 114.2, 11/01/92 |

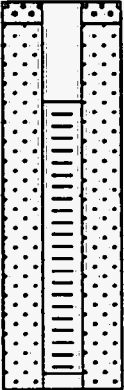

| WELL INSTALLATION |                           | INTERVAL (ft.) | BIT SIZES (in.)                                         |
|-------------------|---------------------------|----------------|---------------------------------------------------------|
| Blank Casing:     | 4.0 in. Trilok SCH 40 PVC | +2.4 to 103.7  | 17.5 in. Rotary from 0.0 to 21.0                        |
| Screen:           | 4.0 in. Trilok SCH 40 PVC | 103.7 to 113.7 | 12.25 in. Rotary from 21.0 to 100.0                     |
| Slot Size:        | 0.010 in.                 |                | 7.88 in. Rotary from 100.0 to 114.3                     |
| End Cap:          | 4.0 in. Trilok SCH 40 PVC | 113.7 to 114.3 | SURFACE CASING (ft.)                                    |
| Grout:            | Enviroplug                | 3.0 to 97.5    | 14.0 in. Steel from 0.0 to 21.0                         |
| Sealant:          | 1/4 in. Bentonite Pellets | 97.5 to 100.8  | 8.625 in. Steel from +2.7 to 100.0                      |
| Sand Pack (U):    | #20-40 Silica Sand        | 100.8 to 114.3 | Cement Pad from +0.29 to 3.0                            |
| Sand Pack (L):    | NA                        |                | Comments: A locking cap was welded to the steel casing. |



# MONITORING WELL COMPLETION LOG 92-13

| Depth<br>(Ft.)         | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                     | Description                                                                                                                                                                                                        |  |  |
|------------------------|-------------|-------------|---------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|
| 55                     |             |             |               |  |  |                                                                                                                                                                                                                    |  |  |
| 60                     |             |             |               |                                                                                    |                                                                                    | 60.0 Interbedded SHALE/SILTSTONE/SANDSTONE, light gray (N6.5) to dark gray (N2.5), medium-grained sandstone, carbonaceous, some coal layers (<1%), increase in clay content, becomes carbonaceous shale/claystone. |  |  |
| 65                     |             |             |               |                                                                                    |                                                                                    |                                                                                                                                                                                                                    |  |  |
| 70                     |             |             |               |                                                                                    |                                                                                    | 70.1 SILTY CLAYSTONE to SILTSTONE, medium dark gray, carbonaceous.                                                                                                                                                 |  |  |
| 75                     |             |             |               |                                                                                    |                                                                                    | 73.8 SANDSTONE, medium light gray (N6.5) to medium gray (N5), very fine to fine grained, bioturbated.                                                                                                              |  |  |
| 80                     |             |             |               |                                                                                    |                                                                                    |                                                                                                                                                                                                                    |  |  |
| 85                     |             |             |               |                                                                                    |                                                                                    | 83.4 SILTY CLAYSTONE, medium light gray (N6.5) to medium dark gray (N5), some carbonaceous material.                                                                                                               |  |  |
| 90                     |             |             |               |                                                                                    |                                                                                    | 88.7 SANDSTONE, medium dark gray (N4.5), fine grained.                                                                                                                                                             |  |  |
| 95                     |             |             |               |                                                                                    |                                                                                    | 89.2 SILTY CLAYSTONE, interbedded with SILTSTONE, medium gray to medium dark gray, carbonaceous.                                                                                                                   |  |  |
| 100                    |             |             |               |                                                                                    |                                                                                    | 88.9-114.3 SANDSTONE, very light gray (N8) to dark gray (N3), mottled, fine to medium grained, bioturbated, carbonaceous material layers, trace of pyrite.                                                         |  |  |
| File: 9213.LOG         |             |             |               |                                                                                    |                                                                                    | Page 2 of 3                                                                                                                                                                                                        |  |  |
| Date Drawn: 02/08/1994 |             |             |               |                                                                                    |                                                                                    |                                                                                                                                                                                                                    |  |  |

# MONITORING WELL COMPLETION LOG 92-13

| Depth<br>(Ft.) | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                        | Graphic<br>Log                                                                    | Description                                                                                                                                                                                                                                                                                                   |
|----------------|-------------|-------------|---------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 105            |             |             |               |  |  | <p>Some dark mafic pebbles, green claystone fragments at 111.7-114.0 feet. DAKOTA SANDSTONE/BURRO CANYON FORMATION contact at 120.0 feet, see lithologic log of monitoring well 92-06.</p> <p>Total depth drilled was 114.3 feet.</p> <p>Stainless steel centralizers were placed at 100.0 and 30.0 feet.</p> |
| 110            |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                               |
| 115            |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                               |
| 120            |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                               |
| 125            |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                               |
| 130            |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                               |
| 135            |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                               |
| 140            |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                               |
| 145            |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                               |
| 150            |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                               |

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Date Drawn: 02/08/1994

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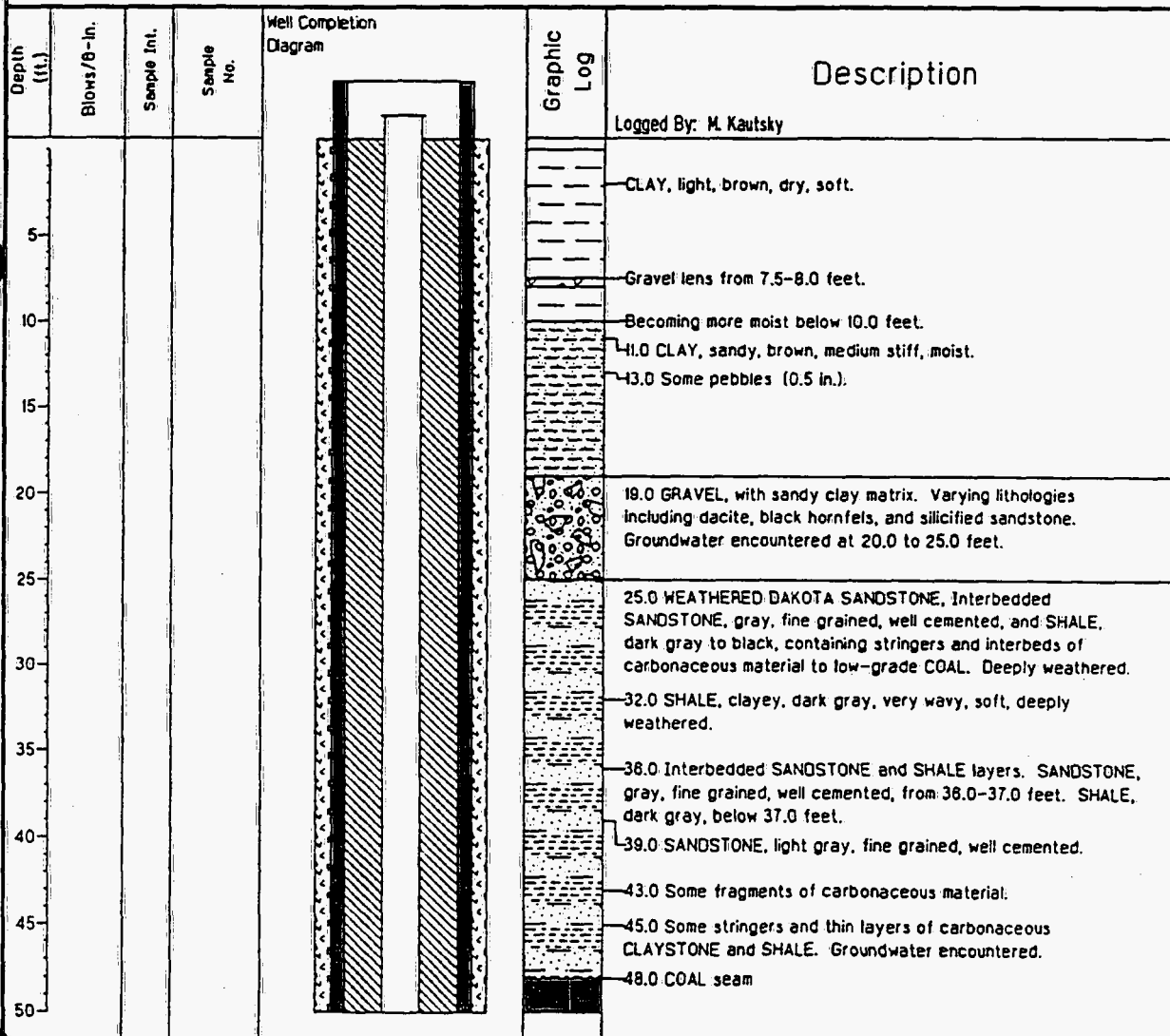


# **MONITORING WELL COMPLETION LOG 93-01 (84-77)**

|                                               |                                      |                                        |
|-----------------------------------------------|--------------------------------------|----------------------------------------|
| Project: Monticello Mill Tailings Site        | North Coordinate (ft.): 10,067.2     | Date Drilled: 08/02/84 - 08/08/84      |
| Location: Monticello, Utah                    | East Coordinate (ft.): 20,454.7      | Drilling Method: Air/Foam Rotary       |
| Site: Millsite, just east of U.S. Highway 191 | Ground Elevation (ft. MSL): 6889.2   | Sampling Method: Rotary Cuttings       |
| Total Depth (ft.): 180.0                      | Measuring Point Elev. (ft.): 6889.98 | Development Date: 10/14/93             |
| Auger Stem Size (in.): NA                     | Auger Head Size (in.): NA            | Water Level (ft. BGL): 107.0, 10/14/93 |

| WELL INSTALLATION                  | INTERVAL (ft.) | BIT SIZES (in.)                    |
|------------------------------------|----------------|------------------------------------|
| Blank Casing: 4.0 in. SCH 40 PVC   | +0.68 to 118.5 | 12.0 in. Rotary from 0.0 to 92.0   |
| Screen: 4.0 in. SCH 40 PVC         | 118.5 to 178.6 | 6.75 in. Rotary from 92.0 to 180.0 |
| Slot Size: 0.020 in.               |                |                                    |
| End Cap: 4.0 in. SCH 40 PVC        | 178.6 to 179.1 |                                    |
| Grout: Volclay                     | 2.0 to 106.0   | SURFACE CASING (ft.)               |
| Sealant: 1/4 in. Bentonite Pellets | 106.0 to 112.0 | 8.125 in. Steel from +1.19 to 92.0 |
| Sand Pack (U): #20-40 Silica Sand  | 112.0 to 114.5 | Cement Pad from +0.33 to 2.0       |
| Sand Pack (L): #10-20 Silica Sand  | 114.5 to 180.0 |                                    |

Comments: Well was reinstalled (formerly known as 84-77).

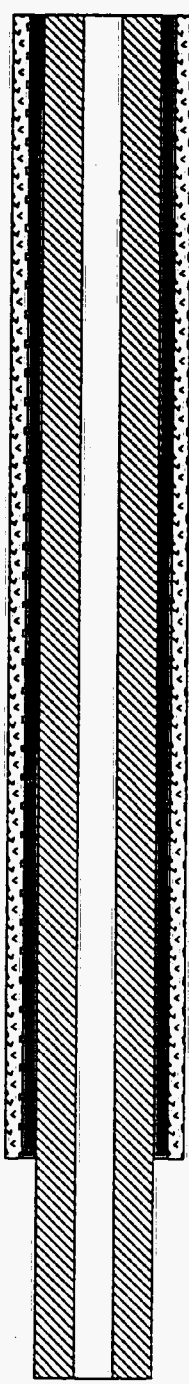
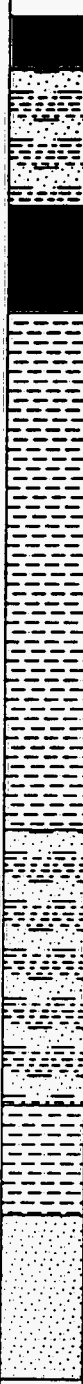


File: 93-01.LOG

Date Drawn: 03/03/1994

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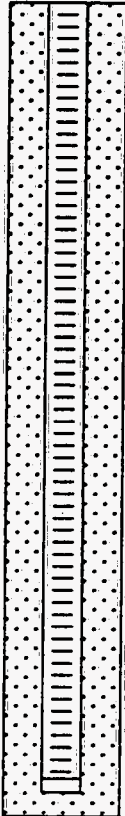

# MONITORING WELL COMPLETION LOG 93-01 (84-77)

| Depth<br>(ft.)         | Blows/6-In. | Sample Int. | Sample<br>No.                                                                                                                    | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                     | Description                                                                                                                                                                                     |
|------------------------|-------------|-------------|----------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        |             |             |                                                                                                                                  |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
| 55                     |             |             |                                                                                                                                  |  |  | 52.0 SANDSTONE, dark gray, fine grained, well cemented, hard. Some carbonaceous material fragments and stringers. Color becomes light gray below 53.0 feet (decrease in carbonaceous material). |
|                        |             |             | 55.0 Interbedded SANDSTONE and COAL stringers.                                                                                   |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
|                        |             |             | 57.0 COAL and SHALE, silty, carbonaceous to 61.0 feet.                                                                           |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
| 60                     |             |             |                                                                                                                                  |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
|                        |             |             | 65.0 SHALE, clayey, dark gray, soft, some carbonaceous material fragments and stringers. Poor cutting return, shale forms balls. |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
| 65                     |             |             |                                                                                                                                  |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
|                        |             |             | 70.0 Grades to interbedded SHALE, black, and stringers of carbonaceous material.                                                 |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
| 70                     |             |             |                                                                                                                                  |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
|                        |             |             | 78.0 Some siliceous SHALE, black, interbedded with stringers of carbonaceous material.                                           |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
| 75                     |             |             |                                                                                                                                  |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
|                        |             |             | 81.0 SANDSTONE, gray, medium hard.                                                                                               |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
| 80                     |             |             | 82.0 Increase in interbedded layers of siliceous SHALE, black, brittle, and stringers of carbonaceous material.                  |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
|                        |             |             | 87.5 SANDSTONE, gray, fine grained, hard. SHALE, thin layer, at 88.5-89.0 feet.                                                  |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
| 85                     |             |             | 90.0 SHALE, gray brown.                                                                                                          |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
| 90                     |             |             | 94.0 SANDSTONE, light brown, fine grained, well cemented.                                                                        |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
| 95                     |             |             | 98.0 Color becoming dark gray.                                                                                                   |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
| 100                    |             |             |                                                                                                                                  |                                                                                    |                                                                                    |                                                                                                                                                                                                 |
| File: 93-01.LOG        |             |             |                                                                                                                                  |                                                                                    |                                                                                    | Page 2 of 4                                                                                                                                                                                     |
| Date Drawn: 03/03/1994 |             |             |                                                                                                                                  |                                                                                    |                                                                                    |                                                                                                                                                                                                 |

# MONITORING WELL COMPLETION LOG 93-01 (84-77)

| Depth<br>(Ft.) | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log         | Description                                                                                                                                           |
|----------------|-------------|-------------|---------------|----------------------------|------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| 105            |             |             |               |                            |                        | 100.0-105.0 Interbedded, SHALE, black (carbonaceous to low grade COAL), with SANDSTONE, light gray to medium gray, fine grained, well cemented, hard. |
| 110            |             |             |               |                            |                        | 108.0 Encountered groundwater.                                                                                                                        |
|                |             |             |               |                            |                        | 107.0 SANDSTONE, gray white, medium grained, poorly cemented, friable, some fragments and stringers of carbonaceous material.                         |
| 115            |             |             |               |                            |                        | 112.0 BURRO CANYON FORMATION, SANDSTONE, white, medium grained, poorly cemented, friable, with blue-green clay stringers.                             |
|                |             |             |               |                            |                        | 115.0 Some pebbles, gray, dark gray, and red brown chert, and coarse-grained sand fragments.                                                          |
| 120            |             |             |               |                            |                        | 120.0 SANDSTONE, white, medium grained, poorly cemented, friable, containing blue-green clayey lenses and pebble zones of chert.                      |
| 125            |             |             |               |                            |                        |                                                                                                                                                       |
| 130            |             |             |               |                            |                        | 132.0 SANDSTONE, fine grained, well cemented, hard.                                                                                                   |
| 135            |             |             |               |                            |                        | 134.0 Drilling becomes easier (softer material).                                                                                                      |
|                |             |             |               |                            |                        | 135.0-140.0 CLAY layer, blue gray.                                                                                                                    |
| 140            |             |             |               |                            |                        | 141.0 SANDSTONE, gray, fine grained, well cemented.                                                                                                   |
| 145            |             |             |               |                            |                        |                                                                                                                                                       |
| 150            |             |             |               |                            |                        |                                                                                                                                                       |
|                |             |             |               |                            | File: 93-01.LOG        | Page 3 of 4                                                                                                                                           |
|                |             |             |               |                            | Date Drawn: 03/03/1994 |                                                                                                                                                       |

# **MONITORING WELL COMPLETION LOG 93-01 (84-77)**

| Depth<br>(ft.) | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                     | Description                                                                                                                                                                                                                    |
|----------------|-------------|-------------|---------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                |             |             |               |                                                                                    |                                                                                    |                                                                                                                                                                                                                                |
| 155            |             |             |               |  |  | 150.0-155.0 SANDSTONE, poorly cemented, friable.                                                                                                                                                                               |
| 160            |             |             |               |                                                                                    |                                                                                    | 160.0 SANDSTONE, white to gray, fine grained, moderately to well cemented, friable, interbedded with layers of SHALE, gray.                                                                                                    |
| 165            |             |             |               |                                                                                    |                                                                                    | Becoming harder at 167.0 feet.                                                                                                                                                                                                 |
| 170            |             |             |               |                                                                                    |                                                                                    | 172.0 Making water in fractures zones?                                                                                                                                                                                         |
| 175            |             |             |               |                                                                                    |                                                                                    | 178.0 Producing water at approximately 12 to 15 gpm.                                                                                                                                                                           |
| 180            |             |             |               |                                                                                    |                                                                                    | Total depth drilled was 180.0 feet. This well was formerly known as 84-77. The PVC, sand, and bentonite were drilled out (10/12/83 - 10/13/83) and the borehole was reamed. The monitoring well was reinstalled and developed. |
| 185            |             |             |               |                                                                                    |                                                                                    |                                                                                                                                                                                                                                |
| 190            |             |             |               |                                                                                    |                                                                                    |                                                                                                                                                                                                                                |
| 195            |             |             |               |                                                                                    |                                                                                    |                                                                                                                                                                                                                                |
| 200            |             |             |               |                                                                                    |                                                                                    |                                                                                                                                                                                                                                |

File: 93-01.LOG

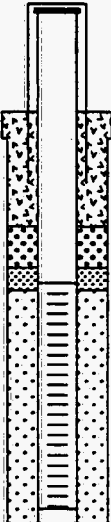
Date Drawn: 03/03/1994

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# **MONITORING WELL COMPLETION LOG 95-01**

|                                        |                                      |                                       |
|----------------------------------------|--------------------------------------|---------------------------------------|
| Project: Monticello Mill Tailings Site | North Coordinate (ft.): 8453.38      | Date Drilled: 12/20/85                |
| Location: Monticello, Utah             | East Coordinate (ft.): 30182.74      | Drilling Method: Air Rotary           |
| Site: OU III/MSG                       | Ground Elevation (ft. MSL): 6872.33  | Sampling Method: None                 |
| Total Depth (ft.): 8.83                | Measuring Point Elev. (ft.): 6675.83 | Development Date: NA                  |
| Auger Stem Size (in.): NA              | Auger Head Size (in.): NA            | Water Level (ft. BGL): 0.91, 01/04/86 |

|                                    |                       |                                                     |
|------------------------------------|-----------------------|-----------------------------------------------------|
| <b>WELL INSTALLATION</b>           | <b>INTERVAL (ft.)</b> | <b>BIT SIZES (in.)</b>                              |
| Blank Casing: 2.0 in. SCH 40 PVC   | -3.5 to 3.5           | 7.875 in. Rotary from 0.0 to 10.0                   |
| Screen: 2.0 in. SCH 40-PVC         | 3.5 to 8.5            |                                                     |
| Slot Size: 0.010 in.               |                       |                                                     |
| End Cap: SCH 40 PVC                | 8.5 to 8.83           | <b>SURFACE CASING (ft.)</b>                         |
| Grout: Concrete (Quickrete)        | 0.0 to 2.25           | 8.0 in. Protective Steel from -3.70 to 1.30         |
| Sealant: 1/4 in. Bentonite Pellets | 2.25 to 3.16          | in. Concrete Pad from -0.3 to 0.3                   |
| Sand Pack (U): #20-40 Silica Sand  | 3.16 to 3.66          |                                                     |
| Sand Pack (L): #10-20 Silica Sand  | 3.66 to 8.83          | Comments: Lithologic log described from well 95-02. |

| Depth (ft.) | Blows/8-in. | Sample Int. | Sample No. | Well Completion Diagram                                                            | Graphic Log | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-------------|-------------|-------------|------------|------------------------------------------------------------------------------------|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |             |             |            |  |             | <p>Logged By: L. Spencer</p> <p>LOESS, ML, includes SAND (60%), silty, dark brown (10YR 4/3), moist, some quartzose pebbles (35%), trace roots.</p> <p>2.0 SAND (50%), ML, very dark gray (10YR 3/1), fine-grained, some silty clay, and SAND (40%), silty, grayish brown (10YR 5/2), mottled, some angular pebbles to 7.5 cm in size (10%), saturated, some root hairs (slightly plastic).</p> <p>4.0 SAND (70%), SM, dark grayish brown (10YR 4/2), fine- to medium-grained, quartzose, poorly graded, saturated, subrounded to rounded pebbles with some chert (25%), size to 8 cm.</p> <p>8.0 GRAVEL (60%), sandy, GM, rounded to subrounded pebbles with some chert, size to 8 cm, saturated. SAND (30%), silty, SM, dark grayish brown (10YR 4/2), poorly graded.</p> <p>Total depth at 8.83 ft.</p> |
| 5           |             |             |            |                                                                                    |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 10          |             |             |            |                                                                                    |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 15          |             |             |            |                                                                                    |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
| 20          |             |             |            |                                                                                    |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

File: 95-01.log

Date Drawn: 03/19/1997

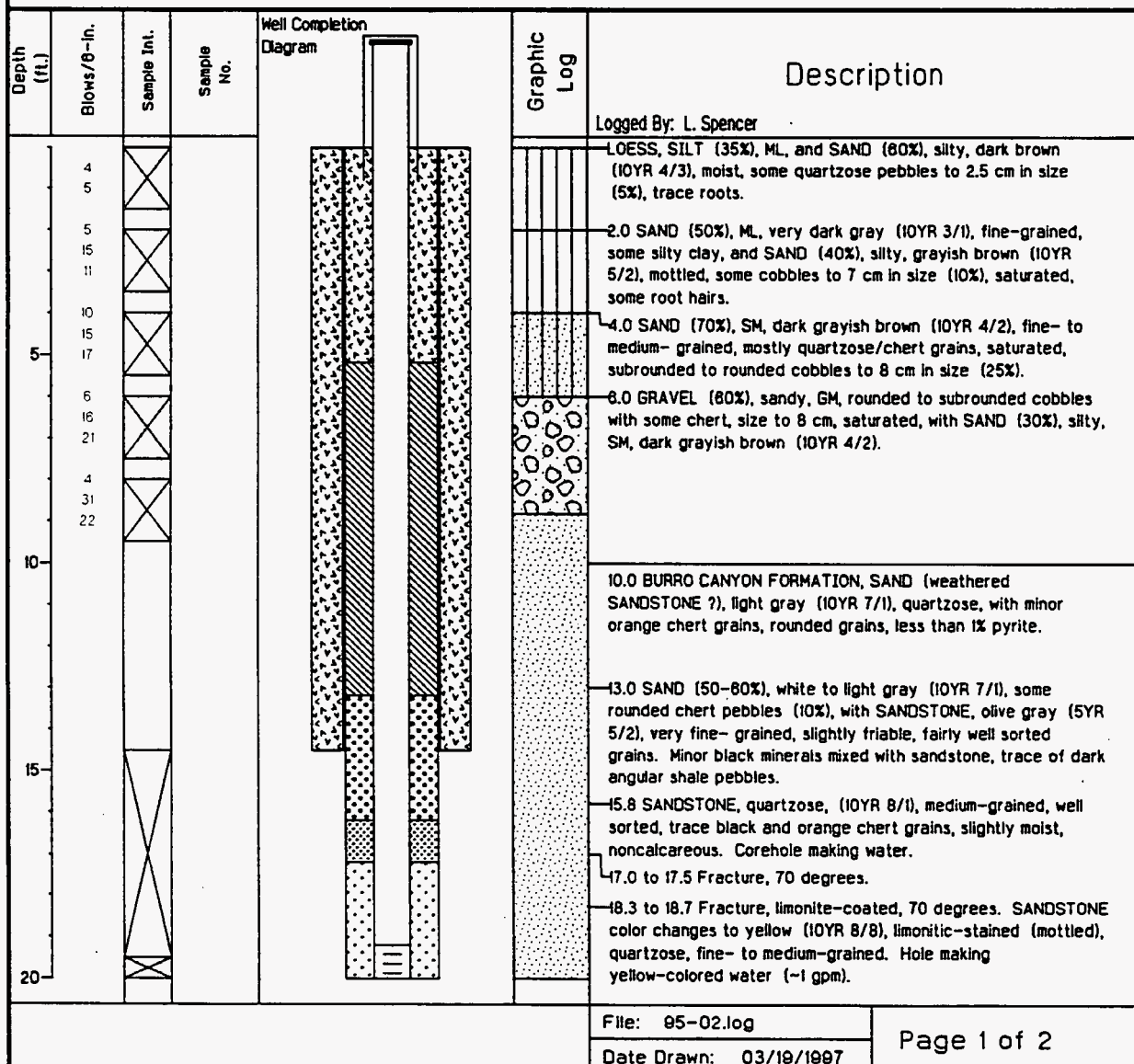
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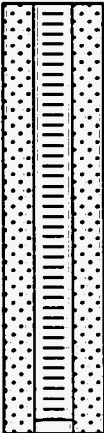

# MONITORING WELL COMPLETION LOG 95-02

|                                        |                                      |                                        |
|----------------------------------------|--------------------------------------|----------------------------------------|
| Project: Monticello Mill Tailings Site | North Coordinate (ft.): 8452.15      | Date Drilled: 12/20/95                 |
| Location: Monticello, Utah             | East Coordinate (ft.): 30170.17      | Drilling Method: Air Rotary/Core       |
| Site: OU III/MSG                       | Ground Elevation (ft. MSL): 6872.99  | Sampling Method: Split Spoon/NX Core   |
| Total Depth (ft.): 29.5                | Measuring Point Elev. (ft.): 6878.99 | Development Date: NA                   |
| Auger Stem Size (in.): NA              | Auger Head Size (in.): NA            | Water Level (ft. BGL): -0.03, 01/04/96 |

| WELL INSTALLATION |                                  | INTERVAL (ft.) | BIT SIZES (in.)                                           |
|-------------------|----------------------------------|----------------|-----------------------------------------------------------|
| Blank Casing:     | 4.0 in. SCH 40 PVC               | -6.0 to 19.2   | 12.25 in. Rotary from 0.0 to 14.5                         |
| Screen:           | 4.0 in. SCH 40 PVC               | 19.2 to 29.2   | 7.875 in. Rotary from 14.5 to 29.5                        |
| Slot Size:        | 0.010 in.                        |                | 3.125 in. Rotary/Core from 14.5 to 29.5                   |
| End Cap:          | SCH 40 PVC                       | 29.2 to 29.5   |                                                           |
| Grout:            | Concrete (Quickrete)             | 0.0 to 5.2     | SURFACE CASING (ft.)                                      |
| Sealant:          | 1/4 in. Bentonite Pellets/Slurry | 5.2 to 16.2    | 6.0 in. Protective Steel from -6.2 to 0.8                 |
| Sand Pack (U):    | #20-40 Silica Sand               | 16.2 to 17.2   | 8.625 in. Steel from 0.0 to 14.5                          |
| Sand Pack (L):    | #10-20 Silica Sand               | 17.2 to 29.5   | in. Concrete Pad from 0.0 to 5.2                          |
|                   |                                  |                | Comments: Stainless Steel Centralizer @ approx. 18-19 ft. |



# MONITORING WELL COMPLETION LOG 95-02

| Depth<br>(Ft.) | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                        | Graphic<br>Log                                                                    | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|----------------|-------------|-------------|---------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 25             |             |             |               |  |  | <p>19.9 SANDSTONE, gray (5Y 6/1), fine-grained, quartzose, moist, dark minerals (~1%) along bedding surfaces, trace pyrite grains. At 21.0 ft, increase in white fine-grained silt or chert fragments and dark chert fragments.</p> <p>22.0 SANDSTONE, very pale brown (10YR 7/8), fine- to medium-grained, mottled with limonite stain on inclined bedding surfaces (up to 20 degrees), pebbles/fragments (5%) up to 1.3 cm size.</p> <p>24.5 Abundant water (~1 gpm), trace of chert pebbles/fragments, bedding inclined 10 to 20 degrees.</p> <p>27.0 Increase in chert and clay fragments (1-2%), up to 1.3 cm size, some mottling, limonite staining, bedding not very apparent.</p> <p>28.0 Color change to light gray (10YR 7/1) (possible oxidation/reduction interface, no apparent texture change), trace pyrite, trace gray-green clay fragments, trace dark minerals along bedding surfaces (slightly coarser grained). At 28.8 to 29.5 ft, becomes coarser grained with 20% chert and clay fragments up to 1.3 cm size, some black chert, trace green sand. At 28.5 ft, color becomes light gray (10YR 6/1).</p> <p>Total depth at 29.5 ft.</p> |
| 30             |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 35             |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 40             |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 45             |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| 50             |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |

File: 95-02.log

Date Drawn: 03/19/1997

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# MONITORING WELL COMPLETION LOG 95-03

Project: Monticello Mill Tailings Site  
 Location: Monticello, Utah  
 Site: OU III/MSG  
 Total Depth (ft.): 11.0  
 Auger Stem Size (in.): NA

North Coordinate (ft.): 8478.55  
 East Coordinate (ft.): 28639.54  
 Ground Elevation (ft. MSL): 8702.6  
 Measuring Point Elev. (ft.): 8704.78  
 Auger Head Size (in.): NA

Date Drilled: 01/04/96  
 Drilling Method: Air Rotary  
 Sampling Method: Split Spoon/Chips  
 Development Date: NA  
 Water Level (ft. BGL): 0.85, 01/04/96

| WELL INSTALLATION |                                     | INTERVAL (ft.) | BIT SIZES (in.)                           |
|-------------------|-------------------------------------|----------------|-------------------------------------------|
| Blank Casing:     | 2.0 in. SCH 40 PVC                  | -2.18 to 5.56  | 7.875 in. Rotary from 0.0 to 11.0         |
| Screen:           | 2.0 in. SCH 40 PVC                  | 5.56 to 10.56  |                                           |
| Slot Size:        | 0.010 in.                           |                |                                           |
| End Cap:          | SCH 40 PVC                          | 10.56 to 10.90 |                                           |
| Grout:            | Concrete (Quickrete)                | 0.0 to 1.5     | SURFACE CASING (ft.)                      |
| Sealant:          | 1/4 in. Bentonite Pellets/Hole Plug | 1.5 to 4.9     | 8.0 in. Protective Steel from -2.5 to 2.5 |
| Sand Pack (U):    | #20-40 Silica Sand                  | 4.9 to 5.3     | in. Concrete Pad from -0.3 to 0.3         |
| Sand Pack (L):    | #10-20 Silica Sand                  | 5.3 to 10.9    | Comments:                                 |

| Depth (ft.) | Blows/6-in. | Sample Int. | Sample No. | Well Completion Diagram | Graphic Log | Description                                                                                                                                                                                                                |
|-------------|-------------|-------------|------------|-------------------------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |             |             |            |                         |             | Logged By: L. Spencer                                                                                                                                                                                                      |
| 37          | X           |             |            |                         |             | SILT (85%), sandy, ML, dark grayish brown (10YR 4/2), some mottling, very dark gray (10YR 3/1), some subrounded pebbles (sandstone) up to 30 mm size (5%), dry, crumbly, minor roots.                                      |
| 36          | X           |             |            |                         |             | 3.0 to 3.5 SAND (80%), silty, ML, dark gray (10YR 4/1), fine-grained, and SILT (10%), clayey, ML, very dark gray (10YR 3/1), plasticity, moist, some rounded cobbles (30%) to 8 cm size.                                   |
| 13          | X           |             |            |                         |             | 3.5 to 5.0 No sample recovery.                                                                                                                                                                                             |
| 3           | X           |             |            |                         |             | 5.0 SAND (80%), silty, very dark gray (10YR 3/1), fine-grained, some clay, some subrounded pebbles (sandstone and igneous) (30%) to 30 mm size, with stringers of SAND (10%), strong brown (7.5YR 5/6), very fine-grained. |
| 4           | X           |             |            |                         |             | 5.7 CLAY, CL, medium plasticity, saturated, root holes and some decayed roots.                                                                                                                                             |
| 8           | X           |             |            |                         |             | 6.0 GRAVEL (70%), GM, subrounded to subangular to 5 cm size, with SAND (30%), silty, dark gray (10YR 4/1), fine-grained, saturated.                                                                                        |
| 4           | X           |             |            |                         |             | 7.0 to 8.0 No sample recovery.                                                                                                                                                                                             |
| 5           | X           |             |            |                         |             | 8.0 GRAVEL, GM, subangular to 4 cm size, with SAND, silty, dark gray (10YR 4/1), saturated.                                                                                                                                |
| 12          | X           |             |            |                         |             | 10.0 BURRO CANYON SANDSTONE, SAND, quartzose, dark grayish brown (10YR 4/2), fine-grained, some red and yellow grains with a few dark minerals, saturated.                                                                 |
| 30          | X           |             |            |                         |             | Total depth at 11.0 ft.                                                                                                                                                                                                    |
| 17          |             |             |            |                         |             |                                                                                                                                                                                                                            |
| 23          |             |             |            |                         |             |                                                                                                                                                                                                                            |
| 10          |             |             |            |                         |             |                                                                                                                                                                                                                            |
| 15          |             |             |            |                         |             |                                                                                                                                                                                                                            |
| 20          |             |             |            |                         |             |                                                                                                                                                                                                                            |

File: 95-03.log

Date Drawn: 03/19/1997

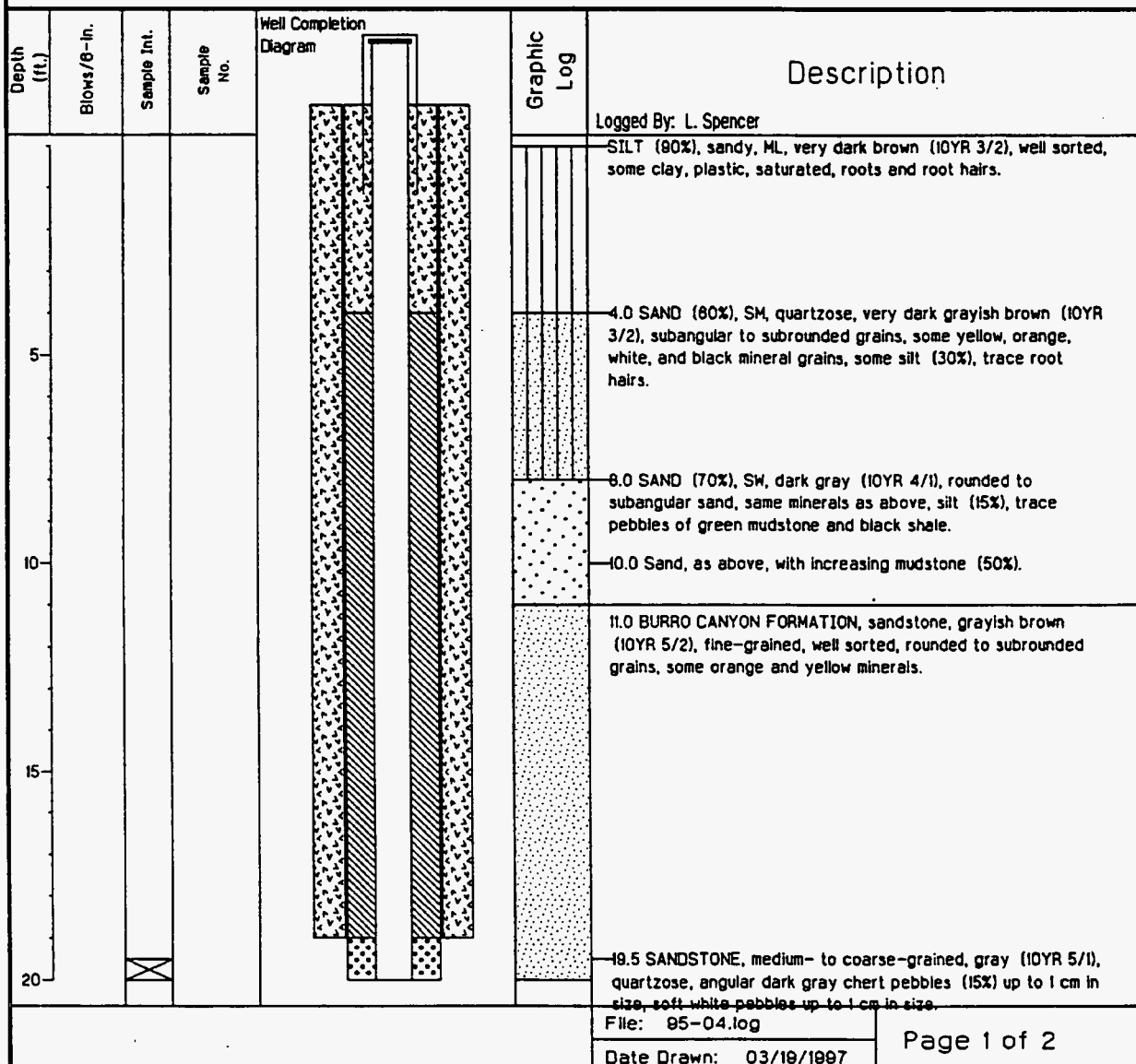
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# **MONITORING WELL COMPLETION LOG 95-04**

|                                        |                                      |                                       |
|----------------------------------------|--------------------------------------|---------------------------------------|
| Project: Monticello Mill Tailings Site | North Coordinate (ft.): 8989.69      | Date Drilled: 01/04/96                |
| Location: Monticello, Utah             | East Coordinate (ft.): 28635.86      | Drilling Method: Air Rotary/Core      |
| Site: OU III/MSG                       | Ground Elevation (ft. MSL): 6702.59  | Sampling Method: Chips/NX Core        |
| Total Depth (ft.): 34.5                | Measuring Point Elev. (ft.): 6706.24 | Development Date: NA                  |
| Auger Stem Size (in.): NA              | Auger Head Size (in.): NA            | Water Level (ft. BGL): 0.23, 01/04/96 |

| WELL INSTALLATION                        | INTERVAL (ft.) | BIT SIZES (in.)                                          |
|------------------------------------------|----------------|----------------------------------------------------------|
| Blank Casing: 4.0 in. SCH 40 PVC         | -3.65 to 24.0  | 12.25 in. Rotary from 0.0 to 19.0                        |
| Screen: 4.0 in. SCH 40 PVC               | 24.0 to 34.0   | 7.875 in. Rotary from 19.0 to 34.33                      |
| Slot Size: 0.010 in.                     |                | 3.125 in. Rotary/Core from 19.5 to 34.5                  |
| End Cap: SCH 40 PVC                      | 34.0 to 34.33  |                                                          |
| Grout: Concrete (Quickrete)              | -1.0 to 4.0    | <b>SURFACE CASING (ft.)</b>                              |
| Sealant: 1/4 in. Bentonite Pellets/Surry | 4.0 to 21.0    | 8.625 in. Steel from -1.0 to 19.0                        |
| Sand Pack (U): #20-40 Silica Sand        | 21.0 to 22.0   | 6.0 in. Protective Steel from -3.85 to 1.15              |
| Sand Pack (L): #10-20 Silica Sand        | 22.0 to 34.33  | in. Concrete from -1.0 to 4.0                            |
|                                          |                | Comments: Stainless Steel Centralizer @ approx. 22-23 ft |



# MONITORING WELL COMPLETION LOG 95-04

| Depth<br>(Ft.) | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------------|-------------|-------------|---------------|----------------------------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 25             |             |             |               |                            |                | <p>19.8 SANDSTONE, fine-grained, gray (10YR 6/1), subrounded to rounded grains, tiny orange, black, and yellow minerals, moist.</p> <p>20.3 SANDSTONE, as above, increasing dark minerals that define low-angle (10 degree) bedding, some pyrite nodules up to 0.5 cm in size.</p> <p>25.0 SANDSTONE, as above, some black siltstone nodules, moist.</p> <p>25.3 SANDSTONE, fine-grained, gray (10YR 6/1), subrounded grains, trace dark minerals, tiny yellow, pink, and black minerals, trace tiny grains of pyrite, saturated.</p> <p>27.5 SANDSTONE, as above, medium-grained.</p>                               |
| 30             |             |             |               |                            |                | <p>30.3 SANDSTONE, fine- to medium-grained, black chert pebbles up to 1 cm in size, soft, white, angular siltstone pebbles up to 0.5 cm in size, tiny orange and yellow minerals, saturated.</p> <p>31.3 SANDSTONE, fine-grained, light gray (10YR 7/1), rounded grains, tiny yellow, white, orange, and dark minerals, trace gray, soft siltstone pebbles less than 0.5 cm in size, saturated.</p> <p>31.8 SANDSTONE, fine- to medium-grained, gray (10YR 6/1), same minerals as above with more dark minerals, white siltstone and orange chert fragments to 0.5 cm in size, trace pyrite crystals, saturated.</p> |
| 35             |             |             |               |                            |                | <p>Total depth at 34.5 ft. Hole making up to 1 gpm water.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| 40             |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 45             |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 50             |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

File: 95-04.log

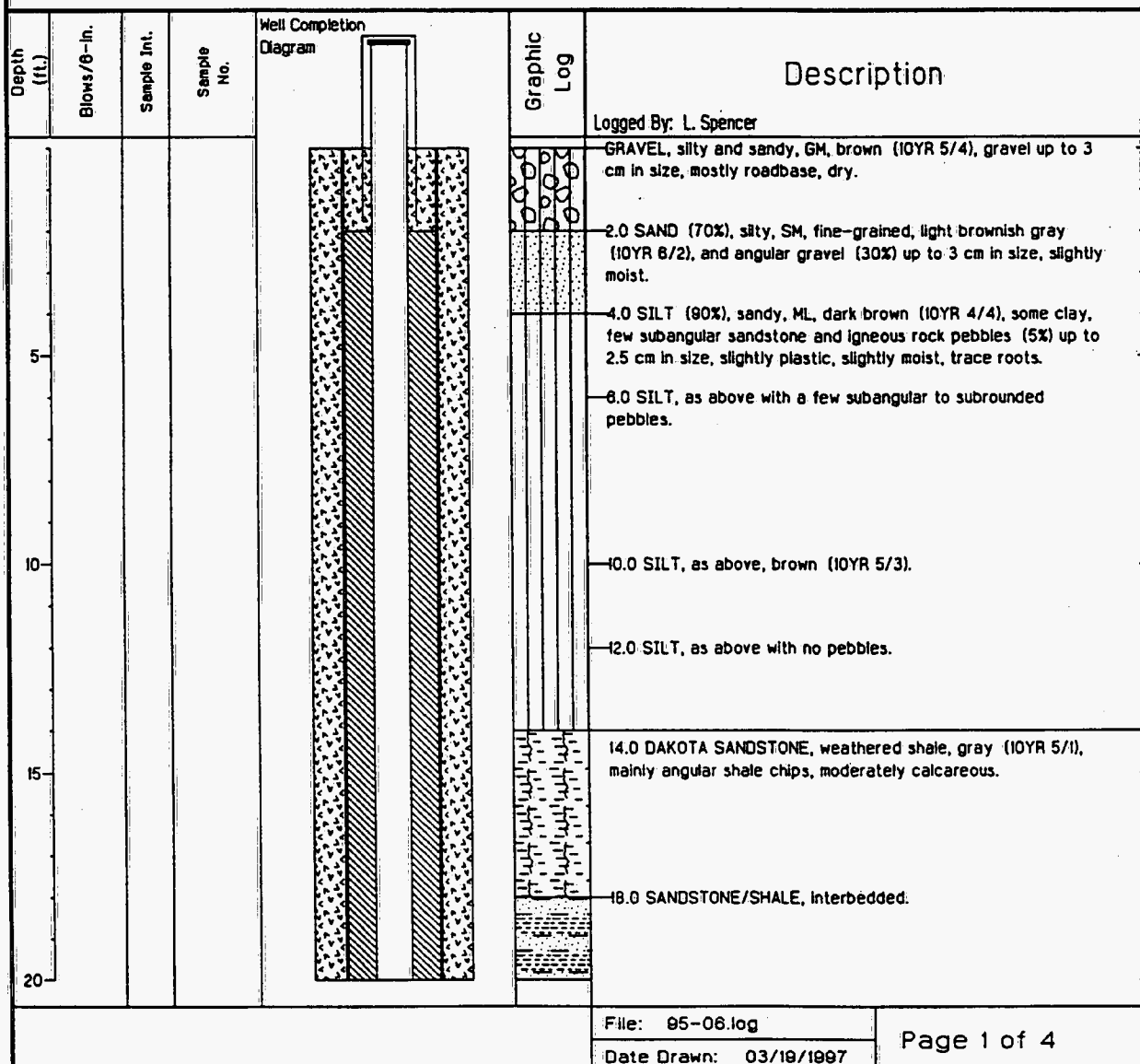
Date Drawn: 03/19/1997

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# **MONITORING WELL COMPLETION LOG 95-06**

|                                        |                                      |                                        |
|----------------------------------------|--------------------------------------|----------------------------------------|
| Project: Monticello Mill Tailings Site | North Coordinate (ft.): 10750.20     | Date Drilled: 01/22/96                 |
| Location: Monticello, Utah             | East Coordinate (ft.): 25350.01      | Drilling Method: Air Rotary/Core       |
| Site: OU III/MS6                       | Ground Elevation (ft. MSL): 6824.0   | Sampling Method: Chips/NX Core         |
| Total Depth (ft.): 105.5               | Measuring Point Elev. (ft.): 6827.03 | Development Date: NA                   |
| Auger Stem Size (in.): NA              | Auger Head Size (in.): NA            | Water Level (ft. BGL): 66.99, 01/25/96 |

|                                    |                       |                                                           |
|------------------------------------|-----------------------|-----------------------------------------------------------|
| <b>WELL INSTALLATION</b>           | <b>INTERVAL (ft.)</b> | <b>BIT SIZES (in.)</b>                                    |
| Blank Casing: 4.0 in. SCH 40 PVC   | -3.03 to 90.12        | 12.25 in. Rotary from 0.0 to 82.0                         |
| Screen: 4.0 in. SCH 40 PVC         | 90.12 to 105.12       | 7.875 in. Rotary from 82.0 to 105.50                      |
| Slot Size: 0.010 in.               |                       | 3.125 in. Rotary/Core from 64.0 to 105.0                  |
| End Cap: SCH 40 PVC                | 105.12 to 105.50      | <b>SURFACE CASING (ft.)</b>                               |
| Grout: Bentonite (Pure Gold)       | 2.0 to 83.50          | 8.625 in. Steel from 0.0 to 82.0                          |
| Sealant: 1/4 in. Bentonite Pellets | 83.50 to 86.50        | 6.0 in. Protective Steel from -3.25 to 1.75               |
| Sand Pack (U): #20-40 Silica Sand  | 86.50 to 88.50        | in. Concrete from 0.0 to 2.0                              |
| Sand Pack (L): #10-20 Silica Sand  | 88.50 to 105.50       | Comments: Stainless Steel Centralizer @ approx. 89-90 ft. |



# MONITORING WELL COMPLETION LOG 95-06

| Depth<br>(Ft.)         | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                            |
|------------------------|-------------|-------------|---------------|----------------------------|----------------|------------------------------------------------------------------------------------------------------------------------|
|                        |             |             |               |                            |                |                                                                                                                        |
| 25                     |             |             |               |                            |                | 25.7 COAL, black (10YR 2/1).                                                                                           |
|                        |             |             |               |                            |                | 28.4 SILTSTONE, gray (10YR 8/1), noncalcareous, very hard, limonite staining in very fine-grained sandstone interbeds. |
| 30                     |             |             |               |                            |                | 30.0 SILTSTONE, clayey (40%), brown, (10YR 5/3), with sandstone (40%), very pale brown (10YR 8/3).                     |
|                        |             |             |               |                            |                | 32.0 SILTSTONE, clayey (80%), grayish brown (2.5Y 8/2), some sandstone (5%).                                           |
| 35                     |             |             |               |                            |                |                                                                                                                        |
|                        |             |             |               |                            |                | 38.0 SILTSTONE, clayey, very dark gray (10YR 3/1), with some coal.                                                     |
| 40                     |             |             |               |                            |                | 40.0 SILTSTONE, clayey, grayish brown (2.5Y 5/2).                                                                      |
|                        |             |             |               |                            |                | 44.0 SILTSTONE, clayey, dark gray (10YR 4/1), some very fine-grained sandstone.                                        |
| 45                     |             |             |               |                            |                |                                                                                                                        |
|                        |             |             |               |                            |                | 48.0 SHALE, carbonaceous, very dark gray (10YR 3/1).                                                                   |
| 50                     |             |             |               |                            |                |                                                                                                                        |
| File: 95-06.log        |             |             |               |                            |                | Page 2 of 4                                                                                                            |
| Date Drawn: 03/19/1997 |             |             |               |                            |                |                                                                                                                        |

# MONITORING WELL COMPLETION LOG 95-06

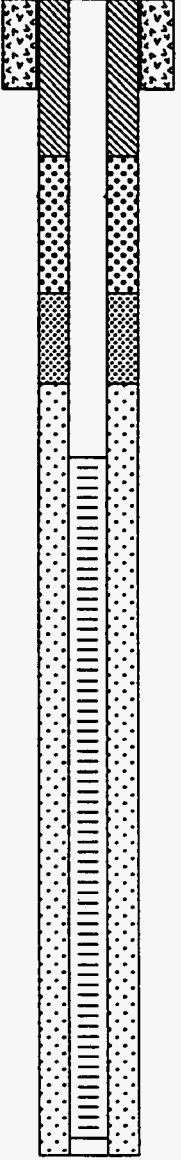
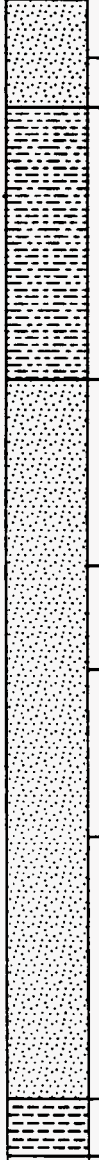
| Depth<br>(ft.) | Blows/6 - In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                                                                                                                                                        |
|----------------|---------------|-------------|---------------|----------------------------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 55             |               |             |               |                            |                | 50.0 SANDSTONE, very fine-grained, light gray (2.5Y 7/1), with iridescent pyrite segregations and interbeds of clayey siltstone, very dark gray (10YR 3/1).                                                                                                                                                                        |
|                |               |             |               |                            |                | 51.5 SANDSTONE, as above with some fine-grained sandstone, dark gray (2.5Y 4/1).                                                                                                                                                                                                                                                   |
|                |               |             |               |                            |                | 54.0 SILTSTONE, gray (2.5Y 5/1), with some very fine-grained sandstone. Sandstone, fine-grained, gray (2.5Y 6/1), with pyrite segregations at 60 to 61 ft.                                                                                                                                                                         |
| 60             |               |             |               |                            |                | 61.0 SHALE, carbonaceous, dark gray (2.5Y 4/1), and siltstone with pyrite segregations.                                                                                                                                                                                                                                            |
|                |               |             |               |                            |                | 64.0 SILTSTONE, gray (10YR 5/1), noncalcareous, moist, finely disseminated carbonaceous material.                                                                                                                                                                                                                                  |
| 65             |               |             |               |                            |                | 66.4 SANDSTONE, very fine-grained, gray (10YR 6/1), bioturbated wavy bedding, carbonaceous mats less than 1 mm thick, trace worm burrow casts less than 1 cm long.                                                                                                                                                                 |
|                |               |             |               |                            |                | 67.5 SANDSTONE, fine-grained, light gray (10YR 7/1), quartzose, well cemented, crossbedded, trace orange mineral grains, dry.                                                                                                                                                                                                      |
| 70             |               |             |               |                            |                | 68.8 SILTSTONE, dark gray (10YR 4/1), noncalcareous.                                                                                                                                                                                                                                                                               |
|                |               |             |               |                            |                | 71.5 CARBONACEOUS SANDSTONE, fine-grained, light gray (10YR 7/1), pyrite segregations, few carbonaceous mats. Abundance of mats increases and bedding is contorted, 72.5 to 73.4 ft.                                                                                                                                               |
| 75             |               |             |               |                            |                | 73.4 CARBONACEOUS SANDSTONE, as above, fine- to medium-grained, a few clay and chert nodules up to 4 mm in size, saturated, low-angle crossbedding, noncalcareous. At 77.5 to 77.9 ft is scoured zone of fine-grained sandstone that has been fractured and filled with chert; zone is slightly moist and contains pyrite nodules. |
| 80             |               |             |               |                            |                | 77.9 BURRO CANYON FORMATION, sandstone, very fine-grained, gray (N8). Horizontal and steeply inclined fractures healed or replaced by pyrite at 80.0 to 80.1 ft.                                                                                                                                                                   |

File: 95-06.log

Date Drawn: 03/19/1997

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# MONITORING WELL COMPLETION LOG 95-06

| Depth<br>(Ft.) | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                     | Description                                                                                                                                                                                                                                                                                                       |
|----------------|-------------|-------------|---------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 85             |             |             |               |  |  | <p>81.3 SANDSTONE, very fine-grained, greenish gray (5G 6/1), noncalcareous, slightly moist.</p>                                                                                                                                                                                                                  |
|                |             |             |               |                                                                                    |                                                                                    | <p>82.4 SILTSTONE, greenish gray (5G 6/1), poorly cemented, slightly moist, some quartz sand (5%) and a few orange grains. Lost 82.5 to 83.3 ft. From 87.0 to 87.7 ft and 87.9 to 88.4 ft, siltstone is light olive gray (5Y 6/1) and hard.</p>                                                                   |
|                |             |             |               |                                                                                    |                                                                                    | <p>88.4 SANDSTONE, fine-grained, light olive gray (5Y 6/1) to greenish-gray (5G 6/1), moist, some siltstone present. From 89.7 to 91.5 ft, sandstone is very light gray (N8) and saturated. Sandstone is medium-grained from 91.5 to 92.5 ft and light gray (N7).</p>                                             |
|                |             |             |               |                                                                                    |                                                                                    | <p>92.5 SANDSTONE, fine-grained, very pale orange (10YR 8/2), saturated, with orange and dark mineral grains. Some crossbedding from 94.1 to 94.8 ft.</p>                                                                                                                                                         |
|                |             |             |               |                                                                                    |                                                                                    | <p>94.8 SANDSTONE, fine-grained, very light gray (N8), saturated, with some greenish gray (5G 6/1) siltstone.</p>                                                                                                                                                                                                 |
|                |             |             |               |                                                                                    |                                                                                    | <p>98.5 SANDSTONE, fine- to medium-grained, light olive gray (5Y 6/1), arkosic, white and gray clay grains, poorly cemented, saturated, mineral grains consist of pyrite and orange and yellow colored types. Lost 102.0 to 104.1 ft. Sandstone is medium- to coarse-grained, arkosic, at 104.1 to 104.25 ft.</p> |
|                |             |             |               |                                                                                    |                                                                                    | <p>104.25 SHALE, greenish gray (5G 6/1), soft, moist. Rotary drilled from 105.0 to 105.5 ft, no core recovered.</p>                                                                                                                                                                                               |
|                |             |             |               |                                                                                    |                                                                                    | <p>Total depth at 105.5 ft.</p>                                                                                                                                                                                                                                                                                   |
| 110            |             |             |               |                                                                                    |                                                                                    |                                                                                                                                                                                                                                                                                                                   |

File: 95-06.log

Date Drawn: 03/19/1997

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# MONITORING WELL COMPLETION LOG 95-07

Project: Monticello Mill Tailings Site  
Location: Monticello, Utah  
Site: OU III/MSG  
Total Depth (ft.): 110.2  
Auger Stem Size (in.): NA

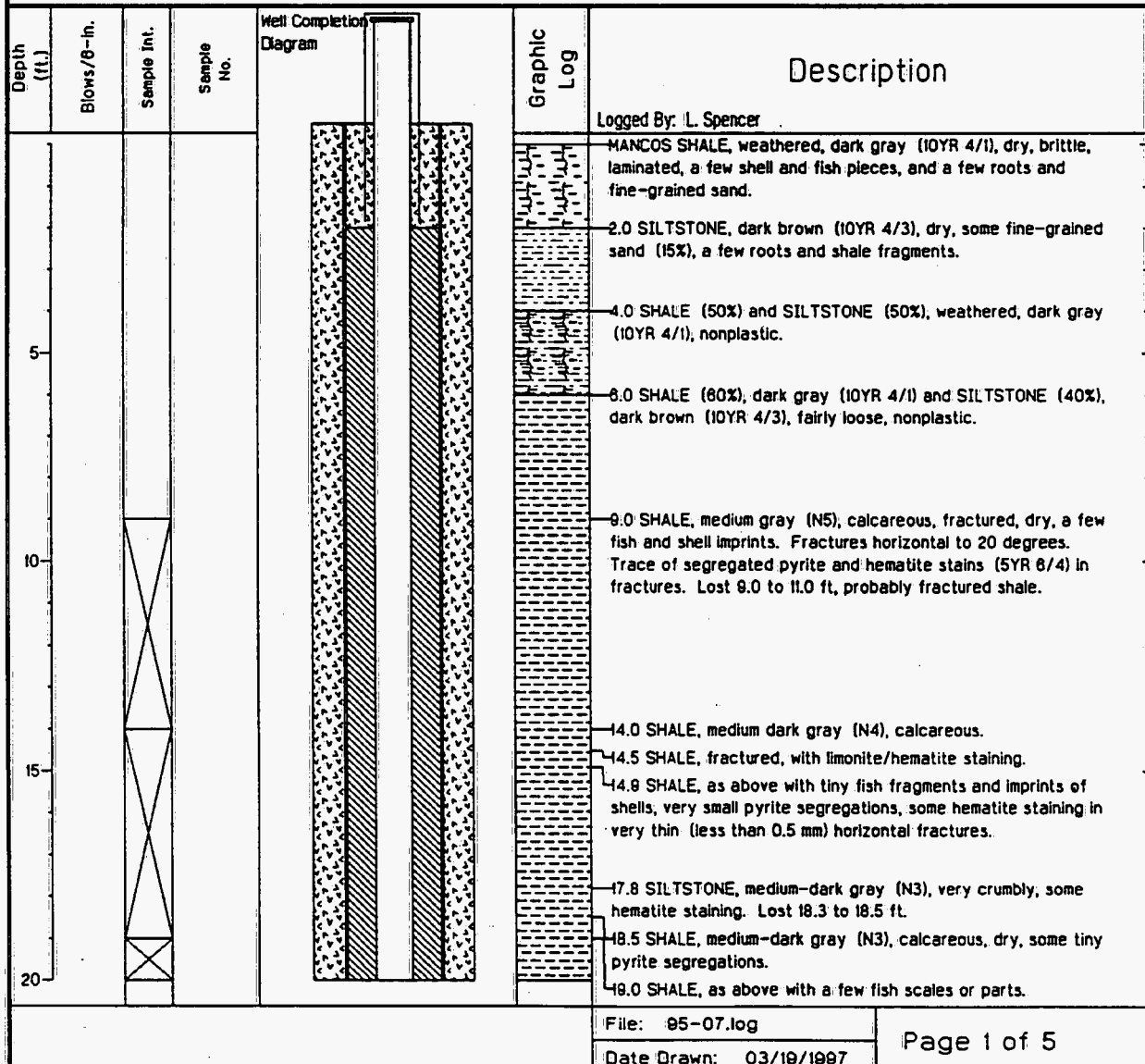
North Coordinate (ft.): 11462.72  
East Coordinate (ft.): 23200.88  
Ground Elevation (ft. MSL): 6880.4  
Measuring Point Elev. (ft.): 6883.34  
Auger Head Size (in.): NA

Date Drilled: 01/23/96  
Drilling Method: Air Rotary/Core  
Sampling Method: Chips/NX Core  
Development Date: NA  
Water Level (ft. BGL): 103.76, 02/08/96

**WELL INSTALLATION**  
Blank Casing: 2.0 in. SCH 40 PVC  
Screen: 2.0 in. SCH 40 PVC  
Slot Size: 0.010 in.  
End Cap: SCH 40 PVC  
Grout: Bentonite (Pure Gold)  
Sealant: 1/4 in. Bentonite Pellets  
Sand Pack (U): #20-40 Silica Sand  
Sand Pack (L): #10-20 Silica Sand

**INTERVAL (ft.)**  
-2.94 to 79.9  
79.9 to 109.9  
109.9 to 110.2  
2.0 to 75.0  
75.0 to 77.0  
77.0 to 77.9  
77.9 to 110.2

**BIT SIZES (in.)**  
12.25 in. Rotary from 0.0 to 75.0  
6.75 in. Rotary from 75.0 to 110.2  
3.125 in. Rotary/Core from 8.0 to 110.2  
**SURFACE CASING (ft.)**  
8.625 in. Steel from 0.0 to 75.0  
6.0 in. Protective Steel from -3.15 to 1.85  
in. Concrete from -0.5 to 2.0  
Comments: Stainless Steel Centralizer @ 79.5 and 109.9



# MONITORING WELL COMPLETION LOG 95-07

| Depth<br>(Ft.) | Blows/8-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----------------|-------------|-------------|---------------|----------------------------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 25             |             |             |               |                            |                | <p>22.0 to 22.5, is an 85 degree fracture coated with limonite/hematite stain.</p> <p>24.0 SHALE, dark gray (N3), calcareous.</p> <p>25.8 SHALE, as above with horizontal fractures.</p> <p>28.1 SHALE, medium gray (N5), becoming softer, calcareous.</p> <p>28.7 SHALE, silty, medium light gray (N8), very soft, slightly plastic, moist, noncalcareous.</p> <p>27.4 SHALE, dark gray (N3), calcareous, trace pyrite segregations and shell or fish imprints.</p> |
| 30             |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| 35             |             |             |               |                            |                | <p>35.3 SHALE, dark gray (N3), calcareous, shell imprints, complete shells and fragments. Zone of "Pycnodonte newberryi" Stanton.</p>                                                                                                                                                                                                                                                                                                                                |
| 40             |             |             |               |                            |                | <p>38.4 SHALE, as above with few pyrite nodules up to 3 mm thick, fewer shells and fragments.</p>                                                                                                                                                                                                                                                                                                                                                                    |
| 45             |             |             |               |                            |                | <p>42.3 SHALE, dark gray (N3), calcareous, no pyrite, few shell fragments.</p> <p>43.7 SHALE, as above with no pyrite or shell fragments.</p>                                                                                                                                                                                                                                                                                                                        |
| 50             |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

File: 95-07.log

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# MONITORING WELL COMPLETION LOG 95-07

| Depth<br>(Ft.)         | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                                                                                                                                                                                      |
|------------------------|-------------|-------------|---------------|----------------------------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 55                     |             |             |               |                            |                | 50.2 BENTONITE, medium gray (N5), very soft, slightly moist, noncalcareous, slightly plastic.                                                                                                                                                                                                                                                                    |
|                        |             |             |               |                            |                | 51.1 SHALE, silty, dark gray (N3), calcareous. Lost 51.8 to 52.3 ft.                                                                                                                                                                                                                                                                                             |
|                        |             |             |               |                            |                | 54.0 SHALE, dark gray (N3), calcareous, a few shell fragments.                                                                                                                                                                                                                                                                                                   |
|                        |             |             |               |                            |                | 55.7 SHALE, silty, medium gray (N5), with some very fine-grained sandstone. Shell fragments more common, calcareous.                                                                                                                                                                                                                                             |
|                        |             |             |               |                            |                | 58.7 DAKOTA SANDSTONE, medium light gray (N8) to medium gray (N5), fine-grained sandstone, some dark gray (N3) shale (40%) mixed in, moist, trace orange minerals.                                                                                                                                                                                               |
| 60                     |             |             |               |                            |                | 57.3 SANDSTONE, medium dark gray (N4), fine-grained, bioturbated, slightly calcareous. Some siltstone, disseminated pyrite, and medium-grained quartzose sandstone with very small green clay-like minerals.                                                                                                                                                     |
|                        |             |             |               |                            |                | 60.7 SANDSTONE, as above with no shell fragments, noncalcareous, small pyrite nodules and tiny vugs with pyrite.                                                                                                                                                                                                                                                 |
|                        |             |             |               |                            |                | 62.4 SANDSTONE, medium light gray (N6), fine-grained, bioturbated, noncalcareous, some large pyrite nodules and disseminated pyrite. At 63.9 ft is a coal layer less than 1 mm thick. At 64.4 ft is a gravel, grayish orange (10YR 7/4), with pebbles up to 2.5 cm in size.                                                                                      |
| 65                     |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                  |
|                        |             |             |               |                            |                | 68.3 SHALE, medium dark gray (N4), soft, clay-like. Coal, black (N2), very low grade, at 68.3 to 68.4 ft.                                                                                                                                                                                                                                                        |
| 70                     |             |             |               |                            |                | 71.1 SANDSTONE, silty, medium light gray (N6), fine-grained, friable, soft, small crossbedded layers, some disseminated pyrite, trace orange minerals, moist, noncalcareous.                                                                                                                                                                                     |
|                        |             |             |               |                            |                | 72.4 SANDSTONE, very light gray (N8), fine-grained, trace orange minerals, thin interbeds of carbonaceous mats, damp.                                                                                                                                                                                                                                            |
| 75                     |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                  |
|                        |             |             |               |                            |                | 78.2 SHALE, dark gray (N3), carbonaceous, soft, trace of scattered pyrite nodules, moist. Coal, grayish black (N2), low grade, and carbonaceous shale, black, soft, moist, trace pyrite nodules up to 1 cm in size and disseminated pyrite, some plant fragments, at 78.2 to 78.8 ft. Shale, light brownish gray (5YR 8/1), soft, clay-like, at 80.4 to 80.5 ft. |
| 80                     |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                  |
| File: 95-07.log        |             |             |               |                            |                | Page 3 of 5                                                                                                                                                                                                                                                                                                                                                      |
| Date Drawn: 03/19/1997 |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                  |

# MONITORING WELL COMPLETION LOG 95-07

| Depth<br>(ft.) | Blows/6-In. | Sample Int. | Sample No. | Well Completion Diagram | Graphic Log | Description                                                                                                                                                                                                                                                                                                              |
|----------------|-------------|-------------|------------|-------------------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                |             |             |            |                         |             |                                                                                                                                                                                                                                                                                                                          |
| 85             |             |             |            |                         |             | 80.5 COAL, black (N1), few pyrite nodules, fairly good grade, from 81.8 to 84.5 ft. Coal, grayish black (N2), low grade, few pyrite nodules, at 80.5 to 81.15 ft, 81.35 to 81.9 ft, and 84.5 to 85.2 ft. Clay, light brownish gray (5YR 6/1), interbedded with low grade coal, few pyrite nodules, at 81.15 to 81.35 ft. |
|                |             |             |            |                         |             | 85.2 SILTSTONE/SHALE, medium gray (N5), soft.                                                                                                                                                                                                                                                                            |
|                |             |             |            |                         |             | 86.8 SILTSTONE/SANDSTONE, light gray (N7), hard siltstone interbedded with very fine-grained sandstone, trace orange minerals and bits of carbon, thin carbonaceous mats throughout, moist. Sandstone, medium light gray (N8), fine-grained, quartzose, few orange and dark mineral grains, moist, at 87.1 to 87.4 ft.   |
| 90             |             |             |            |                         |             | 87.4 SHALE, dark gray (N3), carbonaceous, moist.                                                                                                                                                                                                                                                                         |
|                |             |             |            |                         |             | 90.0 COAL, grayish black (N2), low grade, few pyrite nodules up to 2 cm in size, fractured. Lost 90.3 to 90.8 ft. Carbonaceous shale, dark gray (N3), slightly moist, at 91.3 to 92.0 ft.                                                                                                                                |
|                |             |             |            |                         |             | 92.0 SILTSTONE, medium gray (N5) to medium light gray (N8), few pyrite nodules, dry. Lost 92.3 to 92.8 ft. Sandstone, medium light gray (N8), very fine-grained, interbedded with medium light gray siltstone, few pyrite grains and nodules, crossbedded, slightly moist, at 94.8 to 98.4 ft.                           |
| 95             |             |             |            |                         |             |                                                                                                                                                                                                                                                                                                                          |
|                |             |             |            |                         |             | 98.4 SHALE, medium dark gray (N4), carbonaceous, soft, slightly moist, few pyrite nodules. Interbedded very fine-grained sandstone at 100.0 to 101.5 ft. From 108.7 to 110.2 ft, no pyrite and a thin (0.02 ft) sandstone lens at 108.4 ft.                                                                              |
| 100            |             |             |            |                         |             |                                                                                                                                                                                                                                                                                                                          |
|                |             |             |            |                         |             |                                                                                                                                                                                                                                                                                                                          |
| 105            |             |             |            |                         |             |                                                                                                                                                                                                                                                                                                                          |
|                |             |             |            |                         |             |                                                                                                                                                                                                                                                                                                                          |
| 110            |             |             |            |                         |             |                                                                                                                                                                                                                                                                                                                          |

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| MONITORING WELL COMPLETION LOG 95-07 |             |             |               |                            |                |                          |
|--------------------------------------|-------------|-------------|---------------|----------------------------|----------------|--------------------------|
| Depth<br>(ft.)                       | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description              |
|                                      |             |             |               |                            |                | Total depth at 110.2 ft. |
| 115                                  |             |             |               |                            |                |                          |
| 120                                  |             |             |               |                            |                |                          |
| 125                                  |             |             |               |                            |                |                          |
| 130                                  |             |             |               |                            |                |                          |
| 135                                  |             |             |               |                            |                |                          |
| 140                                  |             |             |               |                            |                |                          |

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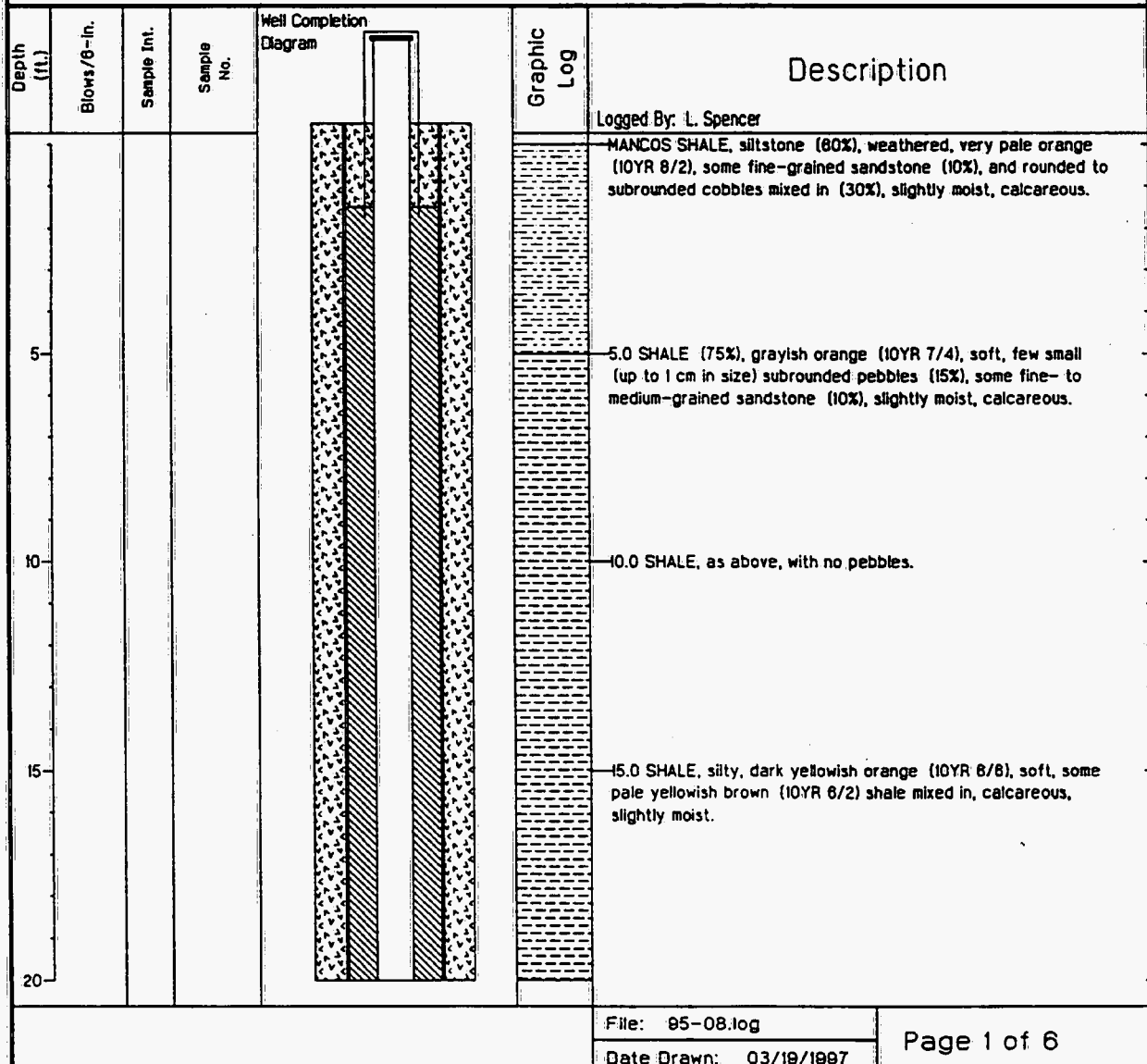
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# **MONITORING WELL COMPLETION LOG 95-08**

|                                        |                                      |                                         |
|----------------------------------------|--------------------------------------|-----------------------------------------|
| Project: Monticello Mill Tailings Site | North Coordinate (ft.): 10128.09     | Date Drilled: 02/13/96                  |
| Location: Monticello, Utah             | East Coordinate (ft.): 28770.16      | Drilling Method: Air Rotary/Core        |
| Site: OU III/MSG                       | Ground Elevation (ft. MSL): 6838.5   | Sampling Method: Chips/NX Core          |
| Total Depth (ft.): 155.0               | Measuring Point Elev. (ft.): 6841.51 | Development Date: NA                    |
| Auger Stem Size (in.): NA              | Auger Head Size (in.): NA            | Water Level (ft. BGL): 124.85, 02/15/96 |

|                                    |                       |                                                         |
|------------------------------------|-----------------------|---------------------------------------------------------|
| <b>WELL INSTALLATION</b>           | <b>INTERVAL (ft.)</b> | <b>BIT SIZES (in.)</b>                                  |
| Blank Casing: 4.0 in. SCH 40 PVC   | -3.01 to 124.63       | 12.25 in. Rotary from 0.0 to 120.0                      |
| Screen: 4.0 in. SCH 40 PVC         | 124.63 to 154.63      | 7.875 in. Rotary from 120.0 to 155.0                    |
| Slot Size: 0.010 in.               |                       | 3.125 in. Rotary/Core from 90.0 to 155.0                |
| End Cap: SCH 40 PVC                | 154.63 to 155.0       | <b>SURFACE CASING (ft.)</b>                             |
| Grout: Bentonite (Pure Gold)       | 150 to 118.90         | 8.625 in. Steel from 0.0 to 120.0                       |
| Sealant: 1/4 in. Bentonite Pellets | 118.90 to 121.90      | 6.0 in. Protective Steel from -3.25 to 1.75             |
| Sand Pack (U): #20-40 Silica Sand  | 121.90 to 122.95      | in. Concrete from -0.5 to 1.5                           |
| Sand Pack (L): #10-20 Silica Sand  | 122.95 to 155.0       | Comments: Stainless Steel Centralizer @ 124.5 and 154.5 |

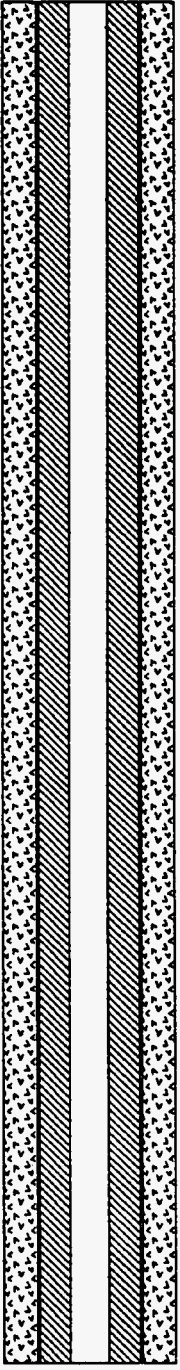



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# MONITORING WELL COMPLETION LOG 95-08

| Depth<br>(Ft.) | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                     | Description                                                                                                                                                                                                                              |
|----------------|-------------|-------------|---------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 25             |             |             |               |  |  |                                                                                                                                                                                                                                          |
| 30             |             |             |               |                                                                                    |                                                                                    | 25.0 DAKOTA SANDSTONE, sandy siltstone (60%), pale yellowish brown (10YR 8/2), sandstone (30%), small pieces of gray shale (10%), slightly moist, calcareous.                                                                            |
| 35             |             |             |               |                                                                                    |                                                                                    | 32.0 CARBONACEOUS SANDSTONE, medium gray (N5), fine-grained, loosely cemented, noncalcareous. At 34 to 35 ft, sandstone is dark yellowish brown (10YR 4/2).                                                                              |
| 40             |             |             |               |                                                                                    |                                                                                    | 35.0 SANDSTONE, fine-grained, quartzose, very pale orange (10YR 8/2), few yellow, orange, and black mineral grains, dry, some gray shale (10%). At 40 to 45 ft, sandstone is grayish orange (10YR 7/4). At 44.5 ft is a moist sandstone. |
| 45             |             |             |               |                                                                                    |                                                                                    | 45.0 SANDSTONE, fine- to medium-grained, dark yellowish orange (10YR 6/6), quartzose, moist.                                                                                                                                             |
| 50             |             |             |               |                                                                                    |                                                                                    |                                                                                                                                                                                                                                          |

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# MONITORING WELL COMPLETION LOG 95-08

| Depth<br>(Ft.)                                               | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                                        |
|--------------------------------------------------------------|-------------|-------------|---------------|----------------------------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 55                                                           |             |             |               |                            |                | 50.0 SANDSTONE, fine-grained, pale yellowish brown (10YR 8/2), quartzose, few tiny yellowish white and dark chert fragments and orange and yellow mineral grains, saturated.                                       |
| 60                                                           |             |             |               |                            |                | 55.0 SANDSTONE, as above, moderate yellowish brown (10YR 5/4), few coaly (black) fragments, saturated. At 63 to 65 ft is olive gray (5Y 4/1), fine-grained sandstone with coal fragments and dark gray (N3) shale. |
| 65                                                           |             |             |               |                            |                | 65.0 SILTSTONE, sandy, medium gray (N5), sticky, few dark gray (N3) shale fragments.                                                                                                                               |
| 70                                                           |             |             |               |                            |                | 70.0 SILTSTONE, light olive gray (5Y 6/1) with very fine-grained sandstone, few yellow, orange, and dark mineral grains, few gray shale fragments.                                                                 |
| 75                                                           |             |             |               |                            |                |                                                                                                                                                                                                                    |
| 80                                                           |             |             |               |                            |                |                                                                                                                                                                                                                    |
| <div>File: 95-08.log</div> <div>Date Drawn: 03/19/1997</div> |             |             |               |                            |                | Page 3 of 6                                                                                                                                                                                                        |

# MONITORING WELL COMPLETION LOG 95-08

| Depth<br>(Ft.) | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                         |
|----------------|-------------|-------------|---------------|----------------------------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 85             |             |             |               |                            |                | 80.0 SHALE, dark gray (N3), trace fine-grained sandstone and coal.                                                                                                                                  |
|                |             |             |               |                            |                | 85.0 SHALE, as above, with at least 50% coal.                                                                                                                                                       |
| 90             |             |             |               |                            |                | 90.0 SHALE, carbonaceous, dark gray (N3) to medium dark gray (N4), some silty claystone and fine-grained sandstone. Lost 94.6 to 95.0 ft.                                                           |
| 95             |             |             |               |                            |                | 95.0 SANDSTONE, very fine-grained, medium dark gray (N4), slightly bioturbated, a filled near-vertical fracture. Medium dark gray siltstone from 96.0 to 96.8 ft, noncalcareous.                    |
|                |             |             |               |                            |                | 96.8 SANDSTONE, as above, medium gray (N5), fluvial crossbedding, trace carbonaceous fragments and bioturbated zones.                                                                               |
| 100            |             |             |               |                            |                | 98.5 SANDSTONE, fine-grained, medium dark gray (N5). Sandstone is crossbedded showing well-defined carbonaceous mats. Some pyrite nodules up to 0.5 cm in size. At 102.0 ft, becomes finer grained. |
| 105            |             |             |               |                            |                | 102.3 SILTSTONE, carbonaceous, medium dark gray (N4) to medium gray (N5). Coal from 102.3 to 102.8 ft. Fracture at 45 degrees at 103.5 ft. Siltstone is dark gray (N5) from 103.5 to 105.5 ft.      |
|                |             |             |               |                            |                | 105.5 CARBONACEOUS SANDSTONE, fine-grained, medium dark gray (N4.5), wavy bedded with carbonaceous fragments, bioturbated.                                                                          |
| 110            |             |             |               |                            |                | 108.3 CARBONACEOUS SANDSTONE, as above, medium gray (N5), carbonaceous mats. Few pyrite nodules at 108.8 ft.                                                                                        |

File: 95-08.log

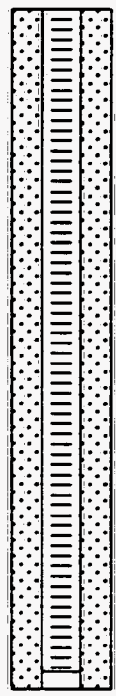

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# MONITORING WELL COMPLETION LOG 95-08

| Depth<br>(Ft.)                                       | Bloss/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|------------------------------------------------------|-------------|-------------|---------------|----------------------------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 115                                                  |             |             |               |                            |                | <p>111.0 CARBONACEOUS SANDSTONE, fine- to medium-grained, pale yellowish brown (10YR 6/2), slightly moist. Few gray chert fragments at 111.7 ft. Lost 112.0 to 112.4 ft. Subangular to subrounded chert fragments up to 1.5 cm in size, few pyrite nodules up to 1 cm in size, and saturated at 112.4 to 112.8 ft.</p> <p>112.8 BURRO CANYON FORMATION, SANDSTONE, very fine-grained, medium light gray (N6), noncalcareous, well cemented, red and black mineral grains, moist. Less well cemented and change to greenish gray from 114.0 to 114.5 ft. Lost 114.5 to 115.0 ft.</p> <p>115.0 SANDSTONE, fine- to medium-grained, light olive gray (5Y 6/1), light gray to black chert pebbles, saturated. Very fine-grained greenish gray (5G 6/1) sandstone at 115.7 to 117.7 ft with trace of black chert pebbles, well cemented, dry.</p> <p>117.7 SANDSTONE, fine-grained, light greenish gray (5GY 8/1), quartzose, less well cemented, noncalcareous, slightly moist. Lost 119.9 to 120.5 ft. Moist to saturated from 120.5 to 121.8 ft.</p> <p>121.8 SANDSTONE, fine- to very fine-grained, quartzose, greenish gray (5GY 8/1) to light greenish gray (5GY 8/1), moderately cemented, moist. Some disseminated pyrite and pyrite nodules at 121.8 to 121.9 ft. Lost 124.8 to 125.2 ft. Few pyrite nodules 125.2 to 126.2 ft. At 126.2 to 126.3 ft is yellowish gray (5Y 8/1), medium-grained sandstone with yellow and orange chert grains, saturated, some pyrite grains and very fine, white chalk/clay attached to quartz grains.</p> <p>126.3 SANDSTONE, fine- to medium-grained, very pale orange (10YR 8/2), quartzose, friable, saturated, few orange and yellow mineral grains and pyrite grains.</p> <p>128.9 SANDSTONE, fine-grained, yellowish gray (5Y 8/1), friable, saturated, orange and yellow mineral grains. Lost 131.3 to 132.1 ft.</p> <p>132.1 SANDSTONE, very fine-grained, pale yellowish brown (10YR 6/2) to very pale orange (10YR 8/2), few orange, yellow, and black mineral grains, saturated. At 132.1 to 132.2 ft is fine-grained sandstone, greenish gray (5GY 6/1), with chert pebbles up to 1 cm in size. At 133.1 and 134.1 ft, a few orange and gray chert chips mixed with medium-grained sandstone. Lost 134.2 to 134.7 ft. At 134.7 to 135.0 ft, medium-grained to very fine-grained, light gray (N7) sandstone with orange and gray pebbles, well cemented, dry.</p> <p>135.0 Lost 135.0 to 136.8 ft.</p> <p>136.8 SILTSTONE, dark greenish gray (5GY 4/1), soft, slightly moist.</p> <p>138.3 SANDSTONE, fine-grained, greenish gray (5GY 6/1), some orange and dark mineral grains, few siltstone fragments up to 1 cm in size disseminated throughout and a few dark chert fragments moist.</p> |
| 120                                                  |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 125                                                  |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 130                                                  |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 135                                                  |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| 140                                                  |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <p>File: 95-08.log</p> <p>Date Drawn: 03/19/1997</p> |             |             |               |                            |                | Page 5 of 6                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |

# **MONITORING WELL COMPLETION LOG 95-08**

| Depth<br>(Ft.)                                                                                         | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                     | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|--------------------------------------------------------------------------------------------------------|-------------|-------------|---------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <div> <div>145</div> <div>150</div> <div>155</div> <div>160</div> <div>165</div> <div>170</div> </div> |             |             |               |  |  | <p>141.3 SANDSTONE, light gray (N7), fine-grained sandstone at 141.3 to 144.5 ft, with orange, yellow, and dark grains, some disseminated pyrite, and clay and chert fragments, medium-grained sandstone at 144.0 ft, saturated.</p> <p>Lost 144.5 to 147.9 ft.</p> <p>147.9 SANDSTONE, fine- to medium-grained, light gray (N7), noncalcareous, saturated. Conglomeratic with chert pebbles up to 2 cm in size, orange and gray pebbles, disseminated pyrite, some fine-grained, friable sandstone with chalky material coating grains. At 148.2 to 149.5 ft is light gray (N7), fine-grained sandstone with few fragments of orange, yellow, and dark minerals, saturated, friable. Lost 149.5 to 149.8 ft.</p> <p>149.8 SANDSTONE, fine-grained, light gray (N7), few yellow, orange, and dark mineral grains, few orange and gray chert fragments, some medium-grained sandstone, trace of soft, white kaolinitic grains, few nodules of soft, green siltstone, saturated, friable. At 150.5 to 153.9 ft, very light gray (N8), very fine-grained sandstone, saturated, with orange, yellow, and dark mineral grains, some disseminated pyrite grains, at 153.0 ft are few dark pebbles up to 1 cm in size and smaller pyrite nodules. At 153.9 to 155.0 ft, sandstone is friable, saturated, has white and chalky nodules and green, silty nodules up to 1 cm in size, pyrite nodules up to 1 mm in size, and few brown pebbles.</p> <p>Total depth at 155.0 ft.</p> |
|                                                                                                        |             |             |               |                                                                                    | <p>File: 95-08.log</p> <p>Date Drawn: 03/10/1997</p>                               | <p>Page 6 of 6</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |

# MONITORING WELL COMPLETION LOG P92-01

Project: Monticello Mill Tailings Site  
 Location: Monticello, Utah  
 Site: Downgradient, ~0.75 mile east of Millsite  
 Total Depth (ft.): 11.5  
 Auger Stem Size (in.): 4.25 I.D. X 7.625 O.D.

North Coordinate (ft.): 8900.9  
 East Coordinate (ft.): 27,438.7  
 Ground Elevation (ft. MSL): 6746.1  
 Measuring Point Elev. (ft.): 6748.6  
 Auger Head Size (in.): 8.0

Date Drilled: 09/22/92  
 Drilling Method: Hollow-Stem Auger  
 Sampling Method: Split Barrel, 3.0 in. X 24 in.  
 Development Date: NA  
 Water Level (ft. BGL): 9.5, 09/23/92

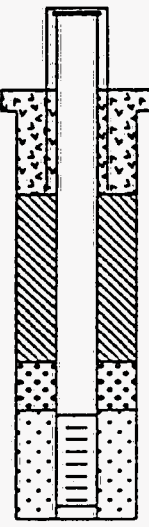
**WELL INSTALLATION**  
 Blank Casing: 2.0 in. Triok SCH 40 PVC  
 Screen: 2.0 in. Triok SCH 40 PVC  
 Slot Size: 0.010 in.  
 End Cap: 2.0 in. Triok SCH 40 PVC  
 Grout: Enviroplug  
 Sealant: 1/4 in. Enviroplug Pellets  
 Sand Pack (U): #20-40 Silica Sand  
 Sand Pack (L): NA

**INTERVAL (ft.)**  
 +2.46 to 8.65  
 8.65 to 11.15  
 11.15 to 11.5  
 2.5 to 7.15  
 7.15 to 8.5  
 8.5 to 11.5

**BIT SIZES (in.)**  
 Not Applicable

**SURFACE CASING (ft.)**  
 4.0 in. Protective Steel from +2.77 to 2.23  
 Cement Pad from +0.4 to 2.5

Comments: CME-75 Drill Rig

| Depth (ft.) | Blows/6-in. | Sample Int. | Sample No. | Well Completion Diagram                                                            | Graphic Log | Description                                                                                                                                                                    |
|-------------|-------------|-------------|------------|------------------------------------------------------------------------------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |             |             |            |  |             | Logged By: D. Traub                                                                                                                                                            |
| 5-8         | X           |             | soil       |                                                                                    |             | SILT, slightly sandy, dark brown (7.5YR 4/3), moist from 0.0 to 0.3 feet, then gradually drier to 2.0 feet. No pebbles, major roots.                                           |
| 12-12       | X           |             | samples    |                                                                                    |             |                                                                                                                                                                                |
| 6-8         | X           |             | not        |                                                                                    |             | 3.0 Dry, caliche from 3.5 to 4.0 feet in root holes and fractures, strong reaction with HCL, firm. At 4.0 feet, 25% rounded igneous pebbles in brown silt, no reaction to HCL. |
| 7-7         | X           |             | saved      |                                                                                    |             |                                                                                                                                                                                |
| 5-8         | X           |             |            |                                                                                    |             | 4.4 SILT/SAND, clayey, strong brown (10YR 5/8), fine grained, stiffer than above, caliche on fissures, slightly moist, sand has no reaction to HCL.                            |
| 12-22       | X           |             |            |                                                                                    |             | 7.0 Moisture increases with depth, one 3 in. igneous cobble. Sand becomes coarser from 7.8-8.0 feet, but 85% is very fine grained.                                             |
| 10-11       | X           |             |            |                                                                                    |             | 8.0 GRAVEL, sandy/silty, brown, with subrounded igneous cobbles to 3 in.                                                                                                       |
| 11-25       | X           |             |            |                                                                                    |             | 10.0 GRAVEL, sandy, igneous pebbles, saturated, only 0.5 foot sampled before refusal.                                                                                          |
| 15-50/5     | X           |             |            |                                                                                    |             | 10.5 DAKOTA SANDSTONE, SANDSTONE, white to light gray, fragments on inner bit, very solid drilling.                                                                            |
| Drilled     |             |             |            |                                                                                    |             | Total depth drilled was 11.5 feet.                                                                                                                                             |
| 30-25/0     | X           |             |            |                                                                                    |             |                                                                                                                                                                                |
| 10          |             |             |            |                                                                                    |             |                                                                                                                                                                                |
| 15          |             |             |            |                                                                                    |             |                                                                                                                                                                                |
| 20          |             |             |            |                                                                                    |             |                                                                                                                                                                                |
| 25          |             |             |            |                                                                                    |             |                                                                                                                                                                                |

File: p9201.log

Date Drawn: 02/07/1994

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MONITORING WELL COMPLETION LOG P92-02

Project: Monticello Mill Tailings Site  
Location: Monticello, Utah  
Site: Downgradient, ~0.75 mile east of Millsite  
Total Depth (ft.): 20.25  
Auger Stem Size (in.): 4.25 ID X 7.625 OD

|                              |          |
|------------------------------|----------|
| North Coordinate (ft.):      | 9563.8   |
| East Coordinate (ft.):       | 27,431.1 |
| Ground Elevation (ft. MSL):  | 6734.8   |
| Measuring Point Elev. (ft.): | 6737.0   |
| Auger Head Size (in.):       | 8.0      |

Date Drilled: 09/24/92  
Drilling Method: Hollow Stem Auger  
Sampling Method: Split Barrel, 3.0 in. X 24 in.  
Development Date: 10/20/92  
Water Level (ft. BGL): 13.93, 10/16/92

## WELL INSTALLATION

|                |                            |                   |
|----------------|----------------------------|-------------------|
| Blank Casing:  | 2.0 in.                    | Trilok SCH 40 PVC |
| Screen:        | 2.0 in.                    | Trilok SCH 40 PVC |
| Slot Size:     | 0.008 in.                  |                   |
| End Cap:       | 2.0 in.                    | Trilok SCH 40 PVC |
| Grout:         | Enviroplug                 |                   |
| Sealant:       | 1/4 in. Enviroplug Pellets |                   |
| Sand Pack (U): | #10-20 Silica Sand         |                   |
| Sand Pack (L): | NA                         |                   |

## INTERVAL (ft)

+2.2 to 17.4  
17.4 to 19.9  
19.9 to 20.25  
2.5 to 14.83  
14.83 to 15.9  
15.9 to 20.25

**BIT SIZES (in.)**

Not Applicable

SURFACE CASING (ft)

4.0 in. Protective Steel from +2.55 to 2.45  
Cement Pad from +0.42 to 2.5

Comments: CME-75 Drill Rig

| Depth<br>(ft.)         | Blows/8-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                           |
|------------------------|-------------|-------------|---------------|----------------------------|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        |             |             |               |                            |                | Logged By: D. Traub                                                                                                                                   |
| 4-8                    | X           |             | soil          |                            |                | SILT, sandy, dark brown (7.5YR 4/2), dry, no pebbles, very minor clay.                                                                                |
| 10-14                  | X           |             | samples       |                            |                | 2.5 Slightly moist, stiff, 2% iron staining.                                                                                                          |
| 9-9                    | X           |             | not           |                            |                | 4.0 Dark brown, slightly moist, stiff, white caliche in fissures from 5.0-6.0 feet, very strong reaction with HCL. Silt has moderate reaction to HCL. |
| 9-11                   | X           |             | saved         |                            |                |                                                                                                                                                       |
| 8-12                   | X           |             |               |                            |                |                                                                                                                                                       |
| 13-12                  | X           |             |               |                            |                |                                                                                                                                                       |
| 4-5                    | X           |             |               |                            |                |                                                                                                                                                       |
| 6-6                    | X           |             |               |                            |                |                                                                                                                                                       |
| 3-5                    | X           |             |               |                            |                |                                                                                                                                                       |
| 6-7                    | X           |             |               |                            |                | 8.6 SAND, silty, dark brown, very fine-grained sand.                                                                                                  |
| 5-6                    | X           |             |               |                            |                | 10.2 GRAVEL, sandy, silty, wet, subrounded igneous pebbles to 1 in.                                                                                   |
| 3-3                    | X           |             |               |                            |                | 10.9 SAND, silty, dark brown (7.5YR 4/2), clayey for 0.1 foot below gravel.                                                                           |
| 0-1                    | X           |             |               |                            |                | 12.3 SAND, silty, black, saturated, very fine-grained sand, minor clay.                                                                               |
| 5-7                    | X           |             |               |                            |                | 13.8 GRAVEL, sandy, black, rounded igneous pebbles to 3/4 in.                                                                                         |
| 2-4                    | X           |             |               |                            |                | 14.0 Subrounded igneous pebbles to 2 in., 75% of pebbles are 3/4 in. or less in size. At 16 feet, 0.2 foot of very silty, fine-grained sand.          |
| 6-2                    | X           |             |               |                            |                | 17.0 SILT, clayey, sandy, black. Only 0.5 foot of sample recovered.                                                                                   |
| 0-1                    | X           |             |               |                            |                | 19.3 BURRO CANYON FORMATION, silty sand on inner bit, no sample recovered in sampler. Augered to 20.25 feet.                                          |
| 7-6                    | X           |             |               |                            |                | Total depth drilled was 20.25 feet.                                                                                                                   |
| 6-50                   | X           |             |               |                            |                |                                                                                                                                                       |
| 50/3"                  | X           |             |               |                            |                |                                                                                                                                                       |
| 25                     |             |             |               |                            |                |                                                                                                                                                       |
| File: p9202.log        |             |             |               |                            |                | Page 1 of 1                                                                                                                                           |
| Date Drawn: 02/07/1994 |             |             |               |                            |                |                                                                                                                                                       |

# **MONITORING WELL COMPLETION LOG P92-03**

Project: Monticello Mill Tailings Site  
 Location: Monticello, Utah  
 Site: Downgradient, 0.5 mile east of Mill site  
 Total Depth (ft.): 13.4  
 Auger Stem Size (in.): 4.25 ID X 7.625 OD

North Coordinate (ft.): 8559.2  
 East Coordinate (ft.): 27,116.4  
 Ground Elevation (ft. MSL): 6737.4  
 Measuring Point Elev. (ft.): 6739.5  
 Auger Head Size (in.): 8.0

Date Drilled: 10/06/92  
 Drilling Method: Hollow-Stem Auger  
 Sampling Method: Split Barrel, 3.0 in. X 24 in.  
 Development Date: 10/17/92  
 Water Level (ft. BGL): 10.14, 10/17/92

**WELL INSTALLATION**  
 Blank Casing: 2.0 in. Triok SCH 40 PVC  
 Screen: 2.0 in. Triok SCH 40 PVC  
 Slot Size: 0.010 in.  
 End Cap: 2.0 in. Triok SCH 40 PVC  
 Grout: Enviroplug  
 Sealant: 1/4 in. Enviroplug Pellets  
 Sand Pack (U): #20-40 Silica Sand  
 Sand Pack (L): NA

**INTERVAL (ft.)**  
 +2.09 to 10.4  
 10.4 to 12.9  
 12.9 to 13.25  
 2.5 to 7.2  
 7.2 to 8.2  
 8.2 to 13.4

**BIT SIZES (in.)**  
 Not Applicable

**SURFACE CASING (ft.)**  
 4.0 in. Protective Steel from +2.46 to 2.54  
 Cement Pad from +0.43 to 2.5

Comments: CME-75 Drill Rig

| Depth (ft.) | Blows/8-in. | Sample Int. | Sample No. | Well Completion Diagram | Graphic Log | Description                                                                                                                                                                                   |
|-------------|-------------|-------------|------------|-------------------------|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |             |             |            |                         |             | Logged By: D. Traub                                                                                                                                                                           |
| 4-6         | X           |             | soil       |                         |             | SAND, silty, dark brown (7.5YR 4/2), slightly moist, moderate reaction to HCL.                                                                                                                |
| 6-7         | X           |             | samples    |                         |             |                                                                                                                                                                                               |
| 4-6         | X           |             | not        |                         |             | 3.0 Minor caliche on root holes and fractures.                                                                                                                                                |
| 6-5         | X           |             | saved      |                         |             |                                                                                                                                                                                               |
| 3-2         | X           |             |            |                         |             | 5.0 Increase in moisture content to 5.8 feet, then soil becomes saturated. Less silt from 5.0 to 5.8 feet, very sandy, dark brown.                                                            |
| 2-2         | X           |             |            |                         |             | 6.0 SAND, clayey, dark grayish brown (10YR 4/2), low to medium plasticity.                                                                                                                    |
| 2-3         | X           |             |            |                         |             | 6.7 SAND, silty, very fine grained, slightly clayey in 0.1 foot intervals, saturated, soft, no caliche, no reaction to HCL.                                                                   |
| 2-4         | X           |             |            |                         |             | 8.0 0.2 foot of gravel, subrounded to subangular, igneous pebbles, very silty, dark brown at 8.0 feet, then dark grayish brown, silty sand as above, saturated. 3% igneous pebbles to 1/4 in. |
| 0-2         | X           |             |            |                         |             | 10.0 SAND, silty, clayey, very dark grayish brown (10YR 4/1), fine-grained sand, saturated, soft, low to medium plasticity.                                                                   |
| 2-3         | X           |             |            |                         |             | 12.0 LOWER DAKOTA SANDSTONE, SANDSTONE, dark greenish gray (5GY 4/1), fragments of sandstone in sampler. Very solid, very hard drilling.                                                      |
| 40/5"       |             |             |            |                         |             | Total depth drilled was 13.4 feet.                                                                                                                                                            |
| 15          |             |             |            |                         |             |                                                                                                                                                                                               |
| 20          |             |             |            |                         |             |                                                                                                                                                                                               |
| 25          |             |             |            |                         |             |                                                                                                                                                                                               |

File: p9203.log

Date Drawn: 02/04/1994

Page 1 of 1

# MONITORING WELL COMPLETION LOG P92-04

Project: Monticello Mill Tailings Site  
 Location: Monticello, Utah  
 Site: Downgradient, ~0.33 mile east of Millsite  
 Total Depth (ft.): 23.0  
 Auger Stem Size (in.): 4.25 ID X 7.625 OD

North Coordinate (ft.): 10,617.3  
 East Coordinate (ft.): 25,380.5  
 Ground Elevation (ft. MSL): 6813.6  
 Measuring Point Elev. (ft.): 6815.9  
 Auger Head Size (in.): 8.0

Date Drilled: 10/06/92  
 Drilling Method: Hollow-Stem Auger  
 Sampling Method: Split Barrel, 3.0 in. X 24 in.  
 Development Date: 10/18/92  
 Water Level (ft. BGL): 21.7, 10/06/92

**WELL INSTALLATION**  
 Blank Casing: 2.0 in. Trilok SCH 40 PVC  
 Screen: 2.0 in. Trilok SCH 40 PVC  
 Slot Size: 0.020 in.  
 End Cap: 2.0 in. Trilok SCH 40 PVC  
 Grout: Enviroplug  
 Sealant: 1/4 in. Enviroplug Pellets  
 Sand Pack (U): #20-40 Silica Sand  
 Sand Pack (L): #10-20 Silica Sand

**INTERVAL (ft.)**  
 +2.3 to 19.8  
 19.8 to 22.31  
 22.31 to 22.63  
 2.5 to 16.2  
 16.2 to 17.33  
 17.33 to 17.83  
 17.83 to 23.0

**BIT SIZES (in.)**  
 Not Applicable

**SURFACE CASING (ft.)**  
 4.0 in. Protective Steel from +2.65 to 2.35  
 Cement Pad from +0.35 to 2.5

Comments: CME-75 Drill Rig

| Depth (ft.) | Blows/6-in. | Sample Int. | Sample No. | Well Completion Diagram | Graphic Log | Description                                                                                                                                                                                               |
|-------------|-------------|-------------|------------|-------------------------|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |             |             |            |                         |             | Logged By: D. Traub                                                                                                                                                                                       |
| 3-3         | X           |             | soil       |                         |             | Lithology and blow counts from SB92-13 (Approximately 3.0 feet west of P92-04) to 20.0 feet. SILT, slightly sandy, dark brown (7.5YR 4/4), fine-grained sand, 5% pebbles to 1/2 in., strong HCL reaction. |
| 4-6         | X           |             | samples    |                         |             | 2.0 Moist to 3.9 feet, then dry, 5% caliche filling in fractures and root holes, strong HCL reaction.                                                                                                     |
| 7-20        | X           |             | not        |                         |             | 4.0 SILT, slightly darker than above (7.5YR 3/2), very stiff, 10% caliche on fractures.                                                                                                                   |
| 30-32       | X           |             | saved      |                         |             | 6.0 Caliche content increasing to 20%, strong HCL reaction.                                                                                                                                               |
| 12-24       | X           |             |            |                         |             | 8.0 Moisture content increasing to slightly moist, several fractured sandstone pebbles to 1 in. at 10.0 feet.                                                                                             |
| 26-25       | X           |             |            |                         |             | 10.0 SILT, slightly sandy, brown (7.5YR 5/3), stiff, slightly moist, 15-20% caliche, 5% scattered pebbles to 1/4 in.                                                                                      |
| 10-13       | X           |             |            |                         |             | 12.0 30% caliche, very strong HCL reaction.                                                                                                                                                               |
| 14-15       | X           |             |            |                         |             |                                                                                                                                                                                                           |
| 7-10        | X           |             |            |                         |             |                                                                                                                                                                                                           |
| 12-17       | X           |             |            |                         |             |                                                                                                                                                                                                           |
| 14-28       | X           |             |            |                         |             |                                                                                                                                                                                                           |
| 43-50       | X           |             |            |                         |             |                                                                                                                                                                                                           |
| 13-27       | X           |             |            |                         |             |                                                                                                                                                                                                           |
| 37-50       | X           |             |            |                         |             |                                                                                                                                                                                                           |
| 12-14       | X           |             |            |                         |             |                                                                                                                                                                                                           |
| 20-23       | X           |             |            |                         |             |                                                                                                                                                                                                           |
| 8-36        | X           |             |            |                         |             |                                                                                                                                                                                                           |
| 50/5"       | X           |             |            |                         |             | 16.5 GRAVEL, fractured sandstone fragments, igneous pebbles, subrounded to subangular.                                                                                                                    |
| 34-56       | X           |             |            |                         |             | 18.0 GRAVEL, sandy, brown with some iron staining, igneous pebbles, 30% fine-to medium-grained sand, pebbles are subrounded to subangular, slightly moist, 30% sand, 30% silt, 40% gravels.               |
| 60/3"       | X           |             |            |                         |             | 21.7 Water encountered.                                                                                                                                                                                   |
| 17-32       | X           |             |            |                         |             | 22.2 DAKOTA SANDSTONE, CLAYSTONE, dark gray, iron stain on fissures, gypsum crystals to 1/2 in. on fractured surfaces. No HCL reaction.                                                                   |
| 26-36       | X           |             |            |                         |             | Total depth drilled was 23.0 feet.                                                                                                                                                                        |
| 30-50/5     | X           |             |            |                         |             |                                                                                                                                                                                                           |

File: p9204.log

Date Drawn: 02/07/1994

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# **MONITORING WELL COMPLETION LOG P92-05**

|                                                  |                                     |                                                 |
|--------------------------------------------------|-------------------------------------|-------------------------------------------------|
| Project: Monticello Mill Tailings Site           | North Coordinate (ft.): 1012.44     | Date Drilled: 09/30/92                          |
| Location: Monticello, Utah                       | East Coordinate (ft.): 25,382.00    | Drilling Method: Hollow-Stem Auger              |
| Site: Downgradient, ~0.33 mile east of Millsite. | Ground Elevation (ft. MSL): 6787.0  | Sampling Method: Split Barrel, 3.0 in. X 24 in. |
| Total Depth (ft.): 7.25                          | Measuring Point Elev. (ft.): 6789.4 | Development Date: NA                            |
| Auger Stem Size (in.): 4.25 I.D. x 7.625 O.D.    | Auger Head Size (in.): 8.0          | Water Level (ft. BGL): 5.25, 10/18/92           |

**WELL INSTALLATION**

Blank Casing: 2.0 in. Trilok SCH 40 PVC

Screen: 2.0 in. Trilok SCH 40 PVC

Slot Size: 0.010 in.

End Cap: 2.0 in. Trilok SCH 40 PVC

Grout: Cement

Sealant: 1/4 in. Enviroplug Pellets

Sand Pack (U): #20-40 Silica Sand

Sand Pack (L): NA

**INTERVAL (ft.)**

+2.4 to 4.4

4.4 to 6.94

6.94 to 7.25

0.0 to 2.83

2.83 to 4.0

4.0 to 7.25

**BIT SIZES (in.)**

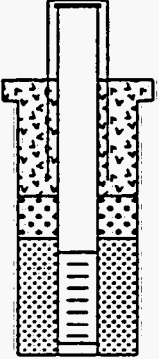






Not Applicable

**SURFACE CASING (ft.)**

4.0 in. Protective Steel from +2.71 to 2.29

Cement Pad from +0.4 to 2.83

Comments: CME-75 Drill Rig

| Depth (ft.) | Blows/6-in. | Sample Int. | Sample No. | Well Completion Diagram                                                            | Graphic Log                                                                         | Description                                                                                                                                                                          |
|-------------|-------------|-------------|------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |             |             |            |  |                                                                                     |                                                                                                                                                                                      |
| 24-20       | X           |             |            |                                                                                    |    | SILT, strong brown (7.5YR 5/8), dry stiff, no caliche, no reaction to HCL. Small sandstone cobble at 0.2 foot.                                                                       |
| 15-12       | X           |             |            |                                                                                    |   | 2.0 SILT, dark brown (7.5YR 5/4), moist, firm, scattered igneous pebbles to 3 in.                                                                                                    |
| 7-5         | X           |             |            |                                                                                    |  | 4.0 Only 0.5 foot of sample recovered, cobble plugged sampler. Fractured igneous pebbles to 3 in. Some claystone, dark gray, in end of sampler.                                      |
| 10-13       | X           |             |            |                                                                                    |  |                                                                                                                                                                                      |
| 4-6         | X           |             |            |                                                                                    |  |                                                                                                                                                                                      |
| 5           |             |             |            |                                                                                    |  | 6.0 DAKOTA SANDSTONE, CLAYSTONE/SILTSTONE, dark gray to 6.7 feet, then color changes to dark brown (10YR 4/3), minor HCL reaction on fracture fillings, gypsum crystals in cavities. |
| 25-30       | X           |             |            |                                                                                    |                                                                                     |                                                                                                                                                                                      |
| 7-14        | X           |             |            |                                                                                    |                                                                                     |                                                                                                                                                                                      |
| 10          |             |             |            |                                                                                    |                                                                                     | Total depth drilled was 7.25 feet. Lithology and blow counts from 0.0-4.0 feet from shallow hole (abandoned) just to west.                                                           |
| 15          |             |             |            |                                                                                    |                                                                                     |                                                                                                                                                                                      |
| 20          |             |             |            |                                                                                    |                                                                                     |                                                                                                                                                                                      |
| 25          |             |             |            |                                                                                    |                                                                                     |                                                                                                                                                                                      |

File: p9205.log

Date Drawn: 02/07/1994

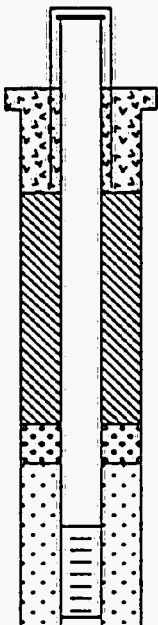
Page 1 of 1

# **MONITORING WELL COMPLETION LOG P92-06**

|                                                         |                                            |                                                        |
|---------------------------------------------------------|--------------------------------------------|--------------------------------------------------------|
| <b>Project:</b> Monticello Mill Tailings Site           | <b>North Coordinate (ft.):</b> 9331.3      | <b>Date Drilled:</b> 10/14/92                          |
| <b>Location:</b> Monticello, Utah                       | <b>East Coordinate (ft.):</b> 25,380.5     | <b>Drilling Method:</b> Hollow-Stem Auger              |
| <b>Site:</b> Downgradient, ~0.33 mile east of Millsite. | <b>Ground Elevation (ft. MSL):</b> 6772.2  | <b>Sampling Method:</b> Split Barrel, 3.0 in. X 24 in. |
| <b>Total Depth (ft.):</b> 14.5                          | <b>Measuring Point Elev. (ft.):</b> 6774.7 | <b>Development Date:</b> 10/18/92                      |
| <b>Auger Stem Size (in.):</b> 4.25 ID X 7.625 OD        | <b>Auger Head Size (in.):</b> 8.0          | <b>Water Level (ft. BGL):</b> 4.85, 10/18/92           |

|                                         |                       |                                           |
|-----------------------------------------|-----------------------|-------------------------------------------|
| <b>WELL INSTALLATION</b>                | <b>INTERVAL (ft.)</b> | <b>BIT SIZES (in.)</b>                    |
| Blank Casing: 2.0 in. Trilok SCH 40 PVC | +2.5 to 11.7          | Not Applicable                            |
| Screen: 2.0 in. Trilok SCH 40 PVC       | 11.7 to 14.2          |                                           |
| Slot Size: 0.020 in.                    |                       |                                           |
| End Cap: 2.0 in. Trilok SCH 40 PVC      | 14.2 to 14.5          | <b>SURFACE CASING (ft.)</b>               |
| Grout: Enviroplug                       | 2.5 to 8.9            | 4.0 in. Protective Steel from +2.9 to 2.1 |
| Sealant: 1/4 in. Enviroplug Pellets     | 8.9 to 10.0           | Cement Pad from +0.28 to 2.5              |
| Sand Pack (U): #10-20 Silica Sand       | 10.0 to 14.5          |                                           |
| Sand Pack (L): NA                       |                       |                                           |

**Comments:** CME-75 Drill Rig

| Depth (ft.) | Blows/ft.-in. | Sample Int. | Sample No. | Well Completion Diagram                                                            | Graphic Log         | Description                                                                                                                                                                    |
|-------------|---------------|-------------|------------|------------------------------------------------------------------------------------|---------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |               |             |            |  |                     |                                                                                                                                                                                |
|             |               |             |            |                                                                                    | Logged By: D. Traub |                                                                                                                                                                                |
| 3-3         |               | X           | soil       |                                                                                    |                     | SAND, silty, clayey, dark brown (7.5 YR 4/2), fine grained, moist, very low plasticity, firm.                                                                                  |
| 3-3         |               | X           | samples    |                                                                                    |                     |                                                                                                                                                                                |
| 0-1         |               | X           | not        |                                                                                    |                     | NOTE: This hayfield was irrigated for several days before installation of well.                                                                                                |
| 1-1         |               | X           | saved      |                                                                                    |                     | Saturated at 3.2 feet.                                                                                                                                                         |
| 0-1         |               | X           |            |                                                                                    |                     | 4.0 SAND, silty, slightly clayey, very fine-grained sand.                                                                                                                      |
| 1-2         |               | X           |            |                                                                                    |                     |                                                                                                                                                                                |
| Push        |               |             |            |                                                                                    |                     | 8.0 Same as above with several scattered igneous and sandstone pebbles, subrounded to subangular, 1.5 in. from 7.8 to 8.0 feet.                                                |
| Push        |               |             |            |                                                                                    |                     |                                                                                                                                                                                |
| 4-7         |               | X           |            |                                                                                    |                     |                                                                                                                                                                                |
| 25-15       |               | X           |            |                                                                                    |                     | 8.1 GRAVEL, sandy, dark brown (7.5 YR 4/4), igneous and sandstone pebbles to 3.0 in., subrounded to subangular, 60% pebbles, 30% sand, fine-to coarse-grained sand, saturated. |
| 28-30       |               | X           |            |                                                                                    |                     |                                                                                                                                                                                |
| 50/5"       |               | X           |            |                                                                                    |                     | 12.0 GRAVEL, sandy, dark brown, saturated.                                                                                                                                     |
| 0-15        |               | X           |            |                                                                                    |                     |                                                                                                                                                                                |
| 33-45       |               | X           |            |                                                                                    |                     | 14.0 DAKOTA SANDSTONE, CLAYSTONE, dark gray (7.5YR 5/0) (variegated light and dark gray), firm, moist, very minor reaction with HCL.                                           |
| 11          |               | X           |            |                                                                                    |                     | Total depth drilled was 14.5 feet.                                                                                                                                             |

File: p9206.log

Date Drawn: 02/04/1994

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# **MONITORING WELL COMPLETION LOG P92-07**

|                                                 |                                     |                                                 |
|-------------------------------------------------|-------------------------------------|-------------------------------------------------|
| Project: Monticello Mill Tailings Site          | North Coordinate (ft.): 10,616.8    | Date Drilled: 10/05/92                          |
| Location: Monticello, Utah                      | East Coordinate (ft.): 24,654.5     | Drilling Method: Hollow-Stem Auger              |
| Site: Downgradient, -0.25 mile east of Millsite | Ground Elevation (ft. MSL): 6817.0  | Sampling Method: Split Barrel, 3.0 in. X 24 in. |
| Total Depth (ft.): 13.66                        | Measuring Point Elev. (ft.): 6817.9 | Development Date: NA                            |
| Auger Stem Size (in.): 4.25 ID X 7.625 OD       | Auger Head Size (in.): 8.0          | Water Level (ft. BGL): DRY, 10/05/92            |

**WELL INSTALLATION**

Blank Casing: 2.0 in. Trilok SCH 40 PVC

Screen: 2.0 in. Triloc SCH 40 PVC

Slot Size: 0.010 in.

End Cap: 2.0 in. Triloc SCH 40 PVC

Grout: Enviroplug

Sealant: 1/4 in. Enviroplug Pellets

Sand Pack (U): #20-40 Silica Sand

Sand Pack (L): NA

**INTERVAL (ft.)**

+0.91 to 10.8

10.8 to 13.35

13.35 to 13.66

2.5 to 9.7

9.7 to 10.7

10.7 to 13.66

**BIT SIZES (in.)**

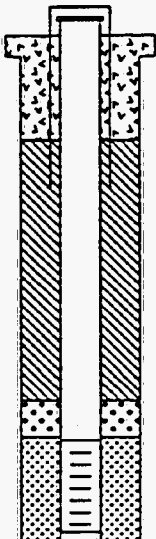

Not Applicable

**SURFACE CASING (ft.)**

4.0 in. Protective Steel from +1.22 to 3.78

Cement Pad from +0.28 to 2.5

Comments: CME-75 Drill Rig

| Depth (ft.) | Blows/6-in. | Sample Int. | Sample No. | Well Completion Diagram                                                            | Graphic Log                                                                        | Description                                                                                                                                                                                |
|-------------|-------------|-------------|------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |             |             |            |                                                                                    |                                                                                    | Logged By: D. Traub                                                                                                                                                                        |
| 6-9         | X           |             | soil       |  |  | SAND/SILT, brown (7.5YR 5/3) to 1.6 feet, then color change to strong brown (7.5YR 4/6), fine-grained sand, dry, strong reaction to HCL.                                                   |
| 9-12        | X           |             | samples    |                                                                                    |                                                                                    |                                                                                                                                                                                            |
| 12-19       | X           |             | not        |                                                                                    |                                                                                    |                                                                                                                                                                                            |
| 22-24       | X           |             | saved      |                                                                                    |                                                                                    |                                                                                                                                                                                            |
| 16-50       | X           |             |            |                                                                                    |                                                                                    |                                                                                                                                                                                            |
| 50/3"       | X           |             |            |                                                                                    |                                                                                    | 4.4 GRAVEL, sandy, dry, fractured igneous pebbles to 3 in. and light gray sandstone fragments. Dry sandy gravel to 5.25 feet, mostly large fractured cobbles. Sample refusal at 5.25 feet. |
| 14-50/3     | X           |             |            |                                                                                    |                                                                                    | 6.0 GRAVEL, silty, sandy, light brown, dry, igneous (subangular) and sandstone (rounded to subrounded) pebbles.                                                                            |
| Drilled     |             |             |            |                                                                                    |                                                                                    | 8.0 GRAVEL, sandy, silty, dry, rounded igneous pebbles to 2 in.                                                                                                                            |
| 20-50/3     | X           |             |            |                                                                                    |                                                                                    |                                                                                                                                                                                            |
| Drilled     |             |             |            |                                                                                    |                                                                                    | 10.0 No sample, very hard drilling from 10.0 to 11.3 feet, then drilling became easier.                                                                                                    |
| 10          |             |             |            |                                                                                    |                                                                                    |                                                                                                                                                                                            |
| Drilled     |             |             |            |                                                                                    |                                                                                    |                                                                                                                                                                                            |
| Drilled     |             |             |            |                                                                                    |                                                                                    |                                                                                                                                                                                            |
| 13-34       | X           |             |            |                                                                                    |                                                                                    | 12.4 DAKOTA SANDSTONE, CLAYSTONE, black, very stiff, moist.                                                                                                                                |
| 50/4"       |             |             |            |                                                                                    |                                                                                    | Total depth drilled was 13.66 feet.                                                                                                                                                        |
| 15          |             |             |            |                                                                                    |                                                                                    |                                                                                                                                                                                            |
| 20          |             |             |            |                                                                                    |                                                                                    |                                                                                                                                                                                            |
| 25          |             |             |            |                                                                                    |                                                                                    |                                                                                                                                                                                            |

File: p9207.log

Date Drawn: 02/04/1994

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# MONITORING WELL COMPLETION LOG P92-09

|                                                       |                                     |                                                 |
|-------------------------------------------------------|-------------------------------------|-------------------------------------------------|
| Project: Monticello Mill Tailings Site                | North Coordinate (ft.): 10,924.5    | Date Drilled: 10/05/82                          |
| Location: Monticello, Utah                            | East Coordinate (ft.): 23,691.6     | Drilling Method: Hollow-Stem Auger              |
| Site: Downgradient, in hayfield just east of Millsite | Ground Elevation (ft. MSL): 6835.3  | Sampling Method: Split Barrel, 3.0 in. X 24 in. |
| Total Depth (ft.): 15.9                               | Measuring Point Elev. (ft.): 6836.2 | Development Date: NA                            |
| Auger Stem Size (in.): 4.25 ID X 7.625 OD             | Auger Head Size (in.): 8.0          | Water Level (ft. BGL): Dry, 10/05/92            |

|                                        |                       |                                            |
|----------------------------------------|-----------------------|--------------------------------------------|
| <b>WELL INSTALLATION</b>               | <b>INTERVAL (ft.)</b> | <b>BIT SIZES (in.)</b>                     |
| Blank Casing: 2.0 in. Triok SCH 40 PVC | +0.91 to 12.6         | Not Applicable                             |
| Screen: 2.0 in. Triok SCH 40 PVC       | 12.6 to 15.1          |                                            |
| Slot Size: 0.010 in.                   |                       |                                            |
| End Cap: 2.0 in. Triok SCH 40 PVC      | 15.1 to 15.33         | <b>SURFACE CASING (ft.)</b>                |
| Grout: Enviroplug                      | 15 to 8.4             | 4.0 in. Protective Steel from +123 to 3.77 |
| Sealant: 1/4 in. Enviroplug Pellets    | 8.4 to 9.75           | Cement Pad from +0.23 to 1.5               |
| Sand Pack (U): #20-40 Silica Sand      | 9.75 to 10.75         |                                            |
| Sand Pack (L): #10-20 Silica Sand      | 10.75 to 15.9         | Comments: CME-75 Drill Rig                 |

| Depth (ft.) | Blows/8-in. | Sample Int. | Sample No. | Well Completion Diagram | Graphic Log | Description                                                                                                                                             |
|-------------|-------------|-------------|------------|-------------------------|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
|             |             |             |            |                         |             | Logged By: D. Traub                                                                                                                                     |
| 5-7         | X           |             | soil       |                         |             | SILTY SAND/SANDY SILT, clayey, brown (10YR 4/4), dry, soft.                                                                                             |
| 9-14        | X           |             | samples    |                         |             | 2.0 CLAYEY, SANDY SILT/SILTY SAND, dark brown (7.5YR 4/2), very fine-grained sand, dry, 3% caliche on fracture surfaces, ~2% igneous pebbles to 3/4 in. |
| 10-15       | X           |             | not        |                         |             |                                                                                                                                                         |
| 18-20       | X           |             | saved      |                         |             |                                                                                                                                                         |
| 14-25       | X           |             |            |                         |             |                                                                                                                                                         |
| 30-42       | X           |             |            |                         |             |                                                                                                                                                         |
| 12-38       | X           |             |            |                         |             |                                                                                                                                                         |
| 46-50/4     | X           |             |            |                         |             |                                                                                                                                                         |
| 22-53/5     | X           |             |            |                         |             |                                                                                                                                                         |
| Drilled     |             |             |            |                         |             |                                                                                                                                                         |
| 22-50/6     | X           |             |            |                         |             | 7.7 GRAVEL, scattered igneous pebbles to 1 1/2 in., abundant caliche, sampler refusal.                                                                  |
| Drilled     |             |             |            |                         |             | 8.0 GRAVEL, sandy, silty, light brown, well graded to 3 in., subrounded to subangular, igneous pebbles.                                                 |
| 30-50/5     | X           |             |            |                         |             | 10.0 GRAVEL, very sandy, silty, light brown, well sorted gravel to 1 1/2 in., rounded to subangular, dry.                                               |
| Drilled     |             |             |            |                         |             | 12.0 Igneous (diorite) and white/light gray sandstone pebbles to 1 1/2 in.                                                                              |
| 14-34       | X           |             |            |                         |             | 15.2 GRAVEL (just above claystone); iron stained, moist.                                                                                                |
| 42-50/5     | X           |             |            |                         |             | 15.3 DAKOTA SANDSTONE, CLAYSTONE, black, moist, very stiff.                                                                                             |
|             |             |             |            |                         |             | Total depth drilled was 15.9 feet.                                                                                                                      |
| 20          |             |             |            |                         |             |                                                                                                                                                         |
| 25          |             |             |            |                         |             |                                                                                                                                                         |

File: p9209.log

Date Drawn: 02/04/1994

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# **MONITORING WELL COMPLETION LOG 31NE93-205**

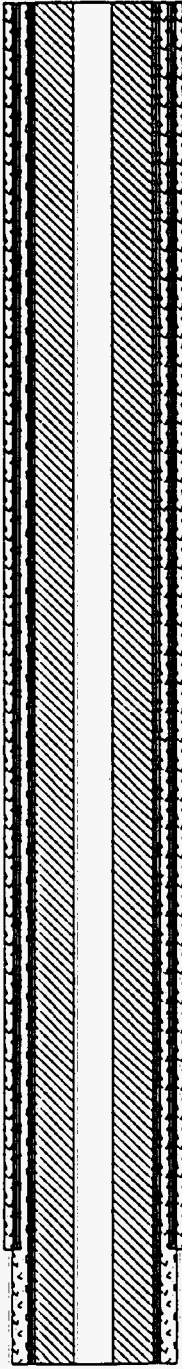

|                                        |                                     |                                          |
|----------------------------------------|-------------------------------------|------------------------------------------|
| Project: Monticello Mill Tailings Site | North Coordinate (ft.): 12299.5     | Date Drilled: 10/26-11/2 and 11/20-22/93 |
| Location: Monticello, Utah             | East Coordinate (ft.): 24151.6      | Drilling Method: Air and Mud Rotary/Core |
| Site: NE of Millsite                   | Ground Elevation (ft. MSL): 6938.4  | Sampling Method: Cuttings/HQ Core        |
| Total Depth (ft.): 241.0               | Measuring Point Elev. (ft.): 6940.6 | Development Date: 11/30 - 12/1/93        |
| Auger Stem Size (in.): NA              | Auger Head Size (in.): NA           | Water Level (ft. BGL): 175, 11/22/93     |

| WELL INSTALLATION                  | INTERVAL (ft.)   | BIT SIZES (in.)                      |
|------------------------------------|------------------|--------------------------------------|
| Blank Casing: 4 in. SCH 80 PVC     | -2.4 to 206.62   | 17 1/2 in. Rotary from 0.0 to 47.5   |
| Screen: 4 in. SCH 80 PVC           | 206.62 to 236.62 | 12 1/4 in. Rotary from 47.5 to 198.0 |
| Slot Size: 0.010/0.020 in.         |                  | 7 7/8 in. Rotary from 198.0 to 241.0 |
| End Cap: 4 in. SCH 80 PVC          | 236.62 to 239.45 |                                      |
| Grout: Enviroplug                  | 3.0 to 197.6     | <b>SURFACE CASING (ft.)</b>          |
| Sealant: 1/4 in. Bentonite Pellets | 197.6 to 201.5   | 13 5/8 in. Steel from 0.0 to 46.0    |
| Sand Pack (U): #20/40              | 201.5 to 202.0   | 8 5/8 in. Steel from 1.0 to 196.0    |
| Sand Pack (L): #10/20              | 202.0 to 239.45  |                                      |

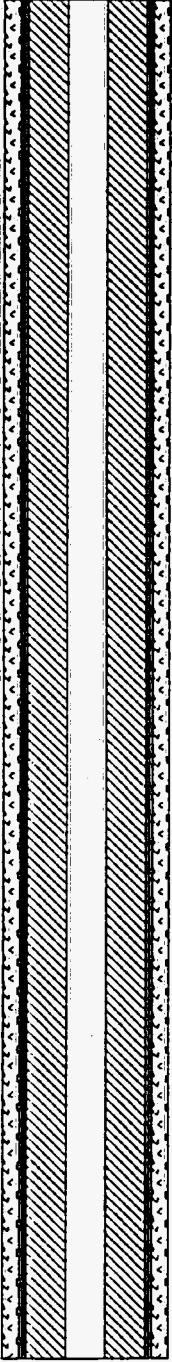
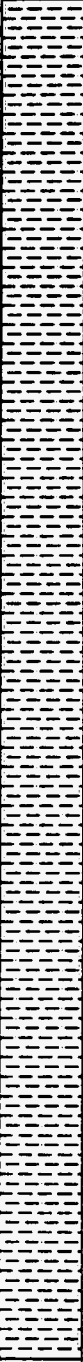
Comments: See well screen note on last page of description.

| Depth (ft.)            | Blows/8-in. | Sample Int. | Sample No. | Well Completion Diagram | Graphic Log | Description                                                                                                                                                           |
|------------------------|-------------|-------------|------------|-------------------------|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        |             |             |            |                         |             | Logged By: C. Goodknight, S. Knutson, D. Traub                                                                                                                        |
|                        |             |             |            |                         |             | SILT, sandy, SM, reddish brown (5YR 4/4), mostly dry, loess, trace pebbles, damp at 4.0 ft.                                                                           |
|                        |             |             |            |                         |             | NOTE: --- Lithologic log for the first 40.0 ft. was taken from a shallow hole drilled 10 ft. to the south and abandoned. ----                                         |
| 5                      |             |             |            |                         |             | 5.0 SANDY GRAVEL, GM, moist to wet, light yellowish brown (10YR 6/4), some highly weathered diorite pebbles and some silty clay, grayish brown (10YR 5/2).            |
| 10                     |             |             |            |                         |             | 10.0 SANDY GRAVEL and cobbles, GM, light yellowish brown (2.5Y 6/4), wet.                                                                                             |
| 15                     |             |             |            |                         |             | 15.0 SILT, sandy, SM, drilling speed increases starting about 15.0 ft. in what likely is silty sand, light yellowish brown (2.5Y 6/4), wet, trace gravel and pebbles. |
| 20                     |             |             |            |                         |             |                                                                                                                                                                       |
| File: 93-205.LOG       |             |             |            |                         |             | Page 1 of 9                                                                                                                                                           |
| Date Drawn: 03/10/1994 |             |             |            |                         |             |                                                                                                                                                                       |

# **MONITORING WELL COMPLETION LOG 31NE93-205**

| Depth<br>(ft.)                                                                                   | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                     | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
|--------------------------------------------------------------------------------------------------|-------------|-------------|---------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <div> <div>25</div> <div>30</div> <div>35</div> <div>40</div> <div>45</div> <div>50</div> </div> |             |             |               |  |  | <div>20.0 SANDY GRAVEL, GM, drilling speed decreases, cobbles more numerous, wet, light yellowish brown.</div> <div>25.0 SILT, sandy, SM, drilling speed increases, some gravel and pebbles.</div> <div>30.0 SILTY SAND, SM, light yellow brown, pebbles and cobbles more abundant.</div> <div>32.0 WEATHERED MANCOS SHALE, BR, yellowish brown pieces, easy to break.</div> <div>38.0 MANCOS SHALE, competent bedrock.</div> <div>48.0 SHALE, medium gray (N5), calcareous, trace of pyrite, dry.</div> |
|                                                                                                  |             |             |               |                                                                                    | <div>File: 93-205.LOG</div> <div>Date Drawn: 03/10/1994</div>                      | <div>Page 2 of 9</div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

# MONITORING WELL COMPLETION LOG 3INE93-205

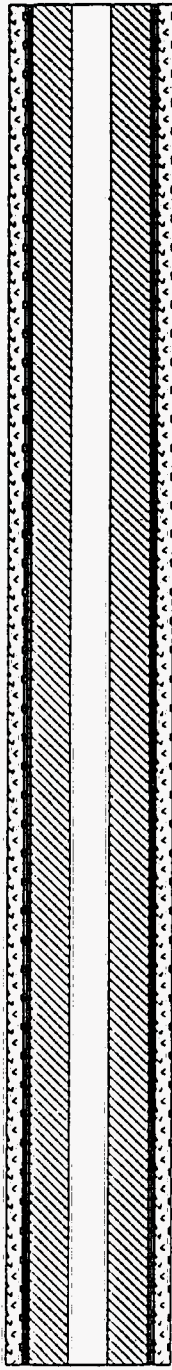



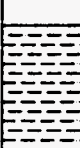







| Depth<br>(Ft.) | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                     | Description                                                                              |
|----------------|-------------|-------------|---------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|
| 55             |             |             |               |  |  | 50.0 SHALE, medium gray (N5) to medium dark gray (N4), calcareous, dry, trace of pyrite. |
|                |             |             |               |                                                                                    |                                                                                    | 53.8 to 54.0: Vertical fracture, no infill.                                              |
|                |             |             |               |                                                                                    |                                                                                    | 56.8 to 57.1: Vertical fracture.                                                         |
|                |             |             |               |                                                                                    |                                                                                    | 57.3 to 58.0: Vertical fracture, no infill.                                              |
|                |             |             |               |                                                                                    |                                                                                    | 58.85 to 59.1: Vertical fracture, no infill.                                             |
| 60             |             |             |               |                                                                                    |                                                                                    | 62.0 to 63.7: Core wet, becomes dry with depth.                                          |
|                |             |             |               |                                                                                    |                                                                                    | 63.3 to 63.5: Some fractures, no infill.                                                 |
| 65             |             |             |               |                                                                                    |                                                                                    | 64.8 to 65.2: Vertical fracture, no infill.                                              |
|                |             |             |               |                                                                                    |                                                                                    | 66.95 to 67.8: Vertical fracture, no infill.                                             |
| 70             |             |             |               |                                                                                    |                                                                                    |                                                                                          |
|                |             |             |               |                                                                                    |                                                                                    | 75.7 to 75.8: Some fractures, no infill.                                                 |
|                |             |             |               |                                                                                    |                                                                                    | 77.0 to 78.0: Trace of fossils.                                                          |
|                |             |             |               |                                                                                    |                                                                                    | 78.2 to 78.5: 30 degree fracture, no infill.                                             |
| 75             |             |             |               |                                                                                    |                                                                                    |                                                                                          |
|                |             |             |               |                                                                                    |                                                                                    |                                                                                          |
| 80             |             |             |               |                                                                                    |                                                                                    |                                                                                          |

File: 93-205.LOG

Date Drawn: 03/10/1994

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# MONITORING WELL COMPLETION LOG 3INE93-205

| Depth<br>(ft.) | Borehole - In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                      | Description                                                                                                                                                           |
|----------------|----------------|-------------|---------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 85             |                |             |               |  |    | 81.7 to 82.2: Vertical fracture, no infill.                                                                                                                           |
|                |                |             |               |                                                                                    |    | 83.2 CLAYSTONE, medium dark gray (N4), moist, grades into bentonitic clay (83.7 to 84.2 ft.), light gray (N7) to medium light gray (N8), high plasticity, very moist. |
|                |                |             |               |                                                                                    |    | Lost core 84.2 to 87.0 ft.                                                                                                                                            |
|                |                |             |               |                                                                                    |    | 87.0 SHALE, medium dark gray (N5).                                                                                                                                    |
| 90             |                |             |               |                                                                                    |    | 90.0 to 90.6: Vertical fracture, no infill.                                                                                                                           |
|                |                |             |               |                                                                                    |    | 90.6 to 90.8: Very broken up.                                                                                                                                         |
|                |                |             |               |                                                                                    |   | Lost core 90.8 to 91.3 ft.                                                                                                                                            |
| 95             |                |             |               |                                                                                    |  | 97.4 CLAYSTONE, gradational contact, dark gray (N3), very slightly moist, calcareous. Vertical fracture at 97.4-97.6 ft.                                              |
| 100            |                |             |               |                                                                                    |  | 101.4 Grades into bentonitic claystone, very light gray (N8) to medium light gray (N6), moist, noncalcareous.                                                         |
|                |                |             |               |                                                                                    |  | 102.55 SHALE, medium dark gray (N4), calcareous.                                                                                                                      |
| 105            |                |             |               |                                                                                    |  | 107.1 DAKOTA SANDSTONE, fine to medium grained, medium light gray (N6), poorly sorted, calcareous, dry, oyster fossils, some bioturbation.                            |
| 110            |                |             |               |                                                                                    |                                                                                     |                                                                                                                                                                       |

File: 93-205.LOG

Date Drawn: 03/10/1994

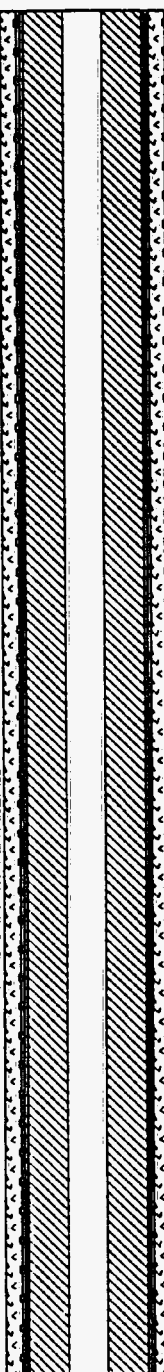

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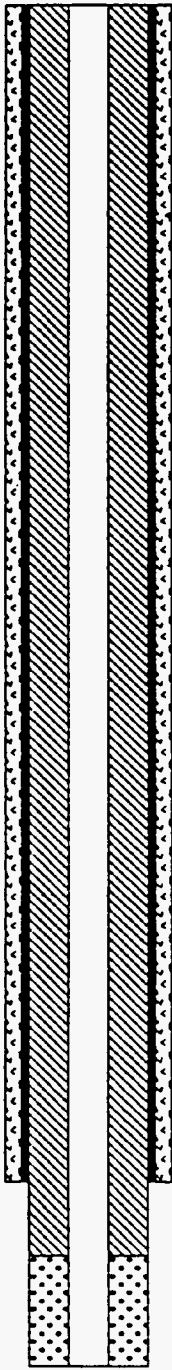














# MONITORING WELL COMPLETION LOG 31NE93-205

| Depth<br>(Ft.)         | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                      |  |
|------------------------|-------------|-------------|---------------|----------------------------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------|--|
|                        |             |             |               |                            |                |                                                                                                                                                  |  |
| 115                    |             |             |               |                            |                |                                                                                                                                                  |  |
| 120                    |             |             |               |                            |                | 120.0 SILTSTONE, gradational contact, brownish black (5YR 2/1), noncalcareous, some carbonaceous material, very slightly moist, trace of pyrite. |  |
|                        |             |             |               |                            |                | 122.0 Very fine layers of carbonaceous material interbedded.                                                                                     |  |
|                        |             |             |               |                            |                | 123.2 CLAYSTONE, gradational contact, dark gray (N3), trace of carbonaceous material.                                                            |  |
| 125                    |             |             |               |                            |                | 124.8 SANDSTONE, gradational contact, very fine grained, medium gray (N5), well cemented, very slightly calcareous.                              |  |
|                        |             |             |               |                            |                | Lost core 125.15 to 125.5 ft.                                                                                                                    |  |
|                        |             |             |               |                            |                | 125.5 Grades into SILTSTONE.                                                                                                                     |  |
|                        |             |             |               |                            |                | 126.5 Grades into SANDSTONE.                                                                                                                     |  |
|                        |             |             |               |                            |                | 127.5 Grades into CLAYSTONE, dark gray (N3).                                                                                                     |  |
| 130                    |             |             |               |                            |                | 130.0 SANDSTONE, fine grained, medium light gray (N6), well cemented, dry.                                                                       |  |
|                        |             |             |               |                            |                | 130.19 Grades into CLAYSTONE, dark gray (N3).                                                                                                    |  |
|                        |             |             |               |                            |                | 133.2 COAL, some pyrite, from 133.2 to 134.6 ft. is a vertical fracture.                                                                         |  |
| 135                    |             |             |               |                            |                | 134.3 Grades into SILTSTONE, dark gray (N3) to grayish black (N2), abundant carbonaceous material, trace of pyrite.                              |  |
|                        |             |             |               |                            |                | 138.3 SILTSTONE/CLAYSTONE, light gray (N7), noncalcareous.                                                                                       |  |
| 140                    |             |             |               |                            |                |                                                                                                                                                  |  |
| File: 93-205.LOG       |             |             |               |                            |                | Page 5 of 9                                                                                                                                      |  |
| Date Drawn: 03/10/1994 |             |             |               |                            |                |                                                                                                                                                  |  |

# MONITORING WELL COMPLETION LOG 3INE93-205

| Depth<br>(Ft.)         | Blows/6-In. | Sample Int. | Sample<br>No.                                                                   | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                     | Description                                                                                                                                                                                                                                |  |  |
|------------------------|-------------|-------------|---------------------------------------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|
|                        |             |             |                                                                                 |                                                                                    |                                                                                    |                                                                                                                                                                                                                                            |  |  |
| 145                    |             |             |                                                                                 |  |  | 140.3 Grades into SANDSTONE, fine grained, light gray (N7).                                                                                                                                                                                |  |  |
|                        |             |             | 140.5 SILTSTONE, brownish black (5YR 2/1), abundant carbonaceous material.      |                                                                                    |                                                                                    |                                                                                                                                                                                                                                            |  |  |
|                        |             |             | 142.8 COAL, fractured, some pyrite, moist.                                      |                                                                                    |                                                                                    |                                                                                                                                                                                                                                            |  |  |
|                        |             |             | 143.35 SILTSTONE, medium gray (N5), to medium light gray (N6), trace of pyrite. |                                                                                    |                                                                                    |                                                                                                                                                                                                                                            |  |  |
|                        |             |             | 147.0 Grades into SANDSTONE, light gray (N7), well cemented.                    |                                                                                    |                                                                                    |                                                                                                                                                                                                                                            |  |  |
|                        |             |             | 148.0 Grades into CLAYSTONE, medium dark gray (N4).                             |                                                                                    |                                                                                    |                                                                                                                                                                                                                                            |  |  |
| 150                    |             |             |                                                                                 |                                                                                    |                                                                                    |                                                                                                                                                                                                                                            |  |  |
|                        |             |             |                                                                                 |                                                                                    |                                                                                    |                                                                                                                                                                                                                                            |  |  |
|                        |             |             |                                                                                 |                                                                                    |                                                                                    |                                                                                                                                                                                                                                            |  |  |
|                        |             |             |                                                                                 |                                                                                    |                                                                                    | 154.3 Some sand, fine grained.                                                                                                                                                                                                             |  |  |
| 155                    |             |             |                                                                                 |                                                                                    |                                                                                    | 154.6 Color becomes grayish black (N2) to brownish black (5YR 2/1), increase in carbonaceous material, some coal, trace of pyrite.                                                                                                         |  |  |
|                        |             |             |                                                                                 |                                                                                    |                                                                                    | 157.0 45 degree fracture, slickensides.                                                                                                                                                                                                    |  |  |
|                        |             |             |                                                                                 |                                                                                    |                                                                                    | 158.8 Grades into SILTSTONE, medium gray (N5) to medium dark gray (N4), very slightly moist, trace of pyrite.                                                                                                                              |  |  |
| 160                    |             |             |                                                                                 |                                                                                    |                                                                                    | 160.0 Vertical fracture.                                                                                                                                                                                                                   |  |  |
|                        |             |             |                                                                                 |                                                                                    |                                                                                    | 162.0 Grades into SANDSTONE, very light gray (N8) to light gray (N7), interbedded siltstone layers, some very thin layers of carbonaceous material, well cemented, subrounded grains, noncalcareous, dry, trace of pyrite (up to 1/4 in.). |  |  |
| 165                    |             |             |                                                                                 |                                                                                    |                                                                                    |                                                                                                                                                                                                                                            |  |  |
|                        |             |             |                                                                                 |                                                                                    |                                                                                    |                                                                                                                                                                                                                                            |  |  |
| 170                    |             |             |                                                                                 |                                                                                    |                                                                                    | 169.0 SILTSTONE, dark gray (N3).                                                                                                                                                                                                           |  |  |
| File: 93-205.LOG       |             |             |                                                                                 |                                                                                    |                                                                                    | Page 6 of 9                                                                                                                                                                                                                                |  |  |
| Date Drawn: 03/10/1994 |             |             |                                                                                 |                                                                                    |                                                                                    |                                                                                                                                                                                                                                            |  |  |

# MONITORING WELL COMPLETION LOG 3INE93-205

| Depth<br>(ft.) | Blows/ft.-In. | Sample Int. | Sample No. | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                      | Description                                                                                                                                                                                                              |
|----------------|---------------|-------------|------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                |               |             |            |                                                                                    |                                                                                     |                                                                                                                                                                                                                          |
| 175            |               |             |            |  |    | SILTSTONE/COAL layer, 170.0 to 172.0 ft., grayish black (N2), trace of pyrite, grades back into siltstone.                                                                                                               |
|                |               |             |            |                                                                                    |    | 171.7 45 degree fracture, slickensides.                                                                                                                                                                                  |
|                |               |             |            |                                                                                    |    | 172.0 SANDSTONE, very fine grained to medium grained, light gray (N7), well cemented, subrounded grains, dry.                                                                                                            |
|                |               |             |            |                                                                                    |    | 173.3 Grades into SILTSTONE, light gray (N7), trace of very thin carbonaceous layers.                                                                                                                                    |
|                |               |             |            |                                                                                    |    | Fractured zone 175.7 to 178.7.                                                                                                                                                                                           |
| 180            |               |             |            |                                                                                    |    | 180.9 SANDSTONE, medium gray (N5) to very light gray (N8), fine to medium grained, subrounded grains, poorly sorted, well cemented, abundant carbonaceous material, bioturbated, some interbedded siltstone layers, dry. |
|                |               |             |            |                                                                                    |  | 184.0 SANDSTONE, silty, very fine grained, color becomes light gray (N7) to white (N9), well cemented, noncalcareous, dry, traces of carbonaceous material, outside of core is friable/silty.                            |
| 185            |               |             |            |                                                                                    |  | 188.2 Grades into CLAYSTONE/SILTSTONE, brownish black (5YR 2/1), 45 degree fracture, slickensides at 188.2 to 188.4 ft.                                                                                                  |
|                |               |             |            |                                                                                    |  | 189.1 Grades into SANDSTONE, light gray (N7), fine to medium grained, subrounded grains, poorly sorted, well cemented, some carbonaceous material. Grades into SILTSTONE, very light gray (N8) at 190.4 ft.              |
| 190            |               |             |            |                                                                                    |  | 190.8 SANDSTONE, fine to medium grained, very light gray (N8) to grayish black (N2), abundant carbonaceous material, trace of coal, poorly sorted, fractured.                                                            |
|                |               |             |            |                                                                                    |  | 191.3 CONGLOMERATE, medium light gray (N6) to pale yellowish brown (10YR 6/2), medium grained matrix, subrounded grains, 30-40% gray chert pebbles, size to 1/2 in., trace of green mudstone clasts.                     |
| 195            |               |             |            |                                                                                    |  | 192.5 SANDSTONE, color becomes grayish brown (5YR 3/2), very broken up, trace of carbonaceous material, moist.                                                                                                           |
|                |               |             |            |                                                                                    |  | 193.4 BURRO CANYON FORMATION SANDSTONE, fine grained, very light gray (N8), well cemented.                                                                                                                               |
| 200            |               |             |            |                                                                                    |  | 194.0 SANDSTONE, medium grained, pale yellowish brown (10YR 6/2), subrounded grains, moderately cemented, poorly sorted, grains friable on outside of core, trace of chert and other mafic minerals, noncalcareous.      |

File: 93-205.LOG

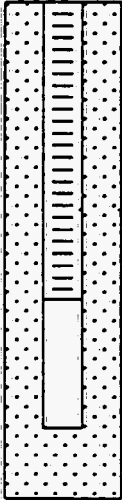
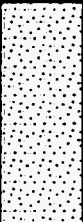
Date Drawn: 03/10/1994

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# MONITORING WELL COMPLETION LOG 3INE93-205

| Depth<br>(ft.)                                        | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                                                                                                                                                                                                              |
|-------------------------------------------------------|-------------|-------------|---------------|----------------------------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                       |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                                          |
| 205                                                   |             |             |               |                            |                | <p>200.0 SANDSTONE, rounded, frosted grains, fine grained, 1-2% red/black chert grains at 204-205 ft. Noncalcareous. Largest piece is about 5 in. long, horizontal fracturing every 3-4 in., medium light gray (N6), wet. Grain size decreases at 205 ft., some gray/green silt blebs up to 3/4 in. at 204.5 ft.</p>                                                                     |
|                                                       |             |             |               |                            |                | <p>205.0 SANDSTONE, fine grained, rounded, well sorted, medium light gray (N6), less than 1% very fine pyrite throughout. Very fractured at 208.4-209.0 ft. Fracturing at 205.7, 208.5, and 207.7 ft. More massive than from 200-205 ft. Color has more green tint below 204.15 ft.</p>                                                                                                  |
| 210                                                   |             |             |               |                            |                | <p>210.0 SANDSTONE, fine to very fine grained, rounded, well sorted, light gray to medium light gray (N7-N8), wet. (Hole was open for 3 hours). Less than 1% pyrite and black siltstone grains throughout. Several pyrite and siltstone pebbles to 1/4 in. Very fractured from 211.6-213.0 ft. and 214.3-214.7 ft., 15 degree fracture at 213.3 ft., other fractures are horizontal.</p> |
| 215                                                   |             |             |               |                            |                | <p>215.0 SANDSTONE, fine grained, light to medium gray, wet, 2-3% siltstone and dark chert grains throughout, frosted rounded grains, noncalcareous, dark grains on bedding.</p>                                                                                                                                                                                                         |
| 220                                                   |             |             |               |                            |                | <p>220.0 SANDSTONE, fine grained, 1-5% black chert pebbles to 1/4 in. throughout, rounded grains, wet, fractured throughout. Many fractures at 223.2-225 ft. Conglomerate (chert pebble), about 0.2 in. at 224.4-224.6 ft., then sandstone. Light to medium gray throughout, darker from 223-225 ft. Gray green clay/claystone in conglomerate to 3/4 in.</p>                            |
| 225                                                   |             |             |               |                            |                | <p>225.0 SANDSTONE, light gray, fine grained, rounded quartz. Only 2.5 ft. recovered. About 5% black/dark gray chert pebbles. At 225-227 ft. is very fine silty sand, unconsolidated, gray, saturated, slight greenish tint, 5% black chert. Coring rate decreased at 227 ft.</p>                                                                                                        |
| 230                                                   |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                                                          |
| <p>File: 93-205.LOG</p> <p>Date Drawn: 03/10/1994</p> |             |             |               |                            |                | <p>Page 8 of 9</p>                                                                                                                                                                                                                                                                                                                                                                       |

# MONITORING WELL COMPLETION LOG 31NE93-205

| Depth<br>(Ft.) | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                        | Graphic<br>Log                                                                    | Description                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
|----------------|-------------|-------------|---------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 235            |             |             |               |  |  | <p>230.0 SANDSTONE, medium gray (N5), rounded, frosted grains, well sorted, 5% black siltstone grains, 20-25% black grains on bedding planes. Noncalcareous, numerous horizontal fractures throughout. At 232.7 ft., sandstone, with 10-15% subrounded chert and siltstone pebbles, grayish green (5G 5/2), fine grained, pebbles to 3/4 in., pyrite to 1/4 in., more competent than sandstone above. This run was sandlocked inside drill rod, pulled string to retrieve.</p> |
| 240            |             |             |               |                                                                                   |                                                                                   | <p>Cored to 235 ft., then reamed with 7 7/8 in. bit to 241 ft.</p>                                                                                                                                                                                                                                                                                                                                                                                                             |
| 245            |             |             |               |                                                                                   |                                                                                   | <p>Well was installed with one 10 ft. 0.010 slot well screen from 228 to 238 ft. and two 10 ft. 0.020 slot well screens from 208 to 228 ft.</p>                                                                                                                                                                                                                                                                                                                                |
| 250            |             |             |               |                                                                                   |                                                                                   | <p>Total depth at 241.0 ft.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 255            |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 260            |             |             |               |                                                                                   |                                                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

File: 93-205.LOG

Date Drawn: 03/10/1994

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# MONITORING WELL COMPLETION LOG 3ISW93-200-1

Project: Monticello Mill Tailings Site  
 Location: Monticello, Utah  
 Site: Millsite  
 Total Depth (ft.): 170.0  
 Auger Stem Size (in.): NA

North Coordinate (ft.): 10218.91  
 East Coordinate (ft.): 20865.32  
 Ground Elevation (ft. MSL): 6895.70  
 Measuring Point Elev. (ft.): 6898.29  
 Auger Head Size (in.): NA

Date Drilled: 9/7-23/93  
 Drilling Method: Air Rotary / Core  
 Sampling Method: Cuttings / HQ core  
 Development Date: 10/27-30/93  
 Water Level (ft. BGL): 114.4, 9/25/93

**WELL INSTALLATION**  
 Blank Casing: 4 in. SCH 80 PVC  
 Screen: 4 in. SCH 80 PVC  
 Slot Size: 0.020 in.  
 End Cap: 4 in. SCH 80 PVC  
 Grout: Enviroplug  
 Sealant: 1/4 in. Bentonite Pellets  
 Sand Pack (U): #20/40  
 Sand Pack (L): #10/20

**INTERVAL (ft.)**  
 -2.59 to 157.15  
 157.15 to 167.15  
 167.15 to 170.0  
 3.0 to 150.5  
 150.5 to 153.5  
 153.5 to 155.0  
 155.0 to 170.0

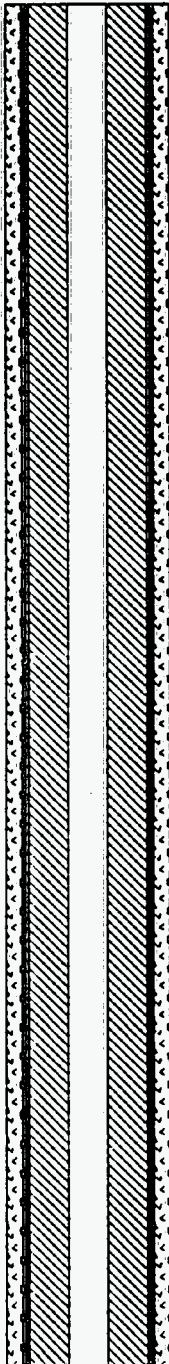










**BIT SIZES (in.)**  
 17 1/2 in. Rotary from 0 to 19.0  
 12 1/4 in. Rotary from 19.0 to 130.0  
 7 7/8 in. Rotary from 130.0 to 170.0

**SURFACE CASING (ft.)**  
 13 5/8 in. 1/2 in. Steel from 0 to 19.0  
 8 5/8 in. Steel from 0 to 130.0

Comments: Well installed 9/24/93, quick recovery.

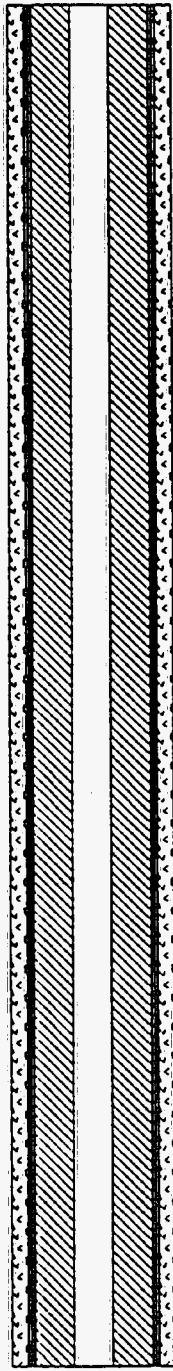
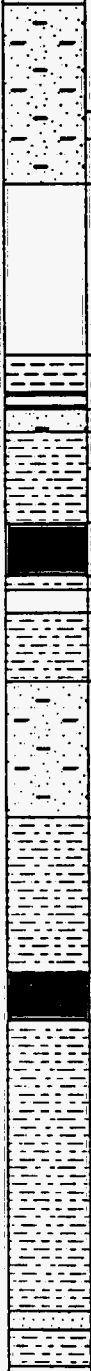
| Depth<br>(ft.)         | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                       |
|------------------------|-------------|-------------|---------------|----------------------------|----------------|---------------------------------------------------------------------------------------------------|
|                        |             |             |               |                            |                | Logged By: T. Bartlett / C. Goodknight                                                            |
|                        |             |             |               |                            |                | SILT, red/brown, trace sand and gravel, dry to slightly moist.                                    |
| 5                      |             |             |               |                            |                | 4.0 Same as above, with gravel and cobbles, difficult drilling.                                   |
| 10                     |             |             |               |                            |                | 10.5 WEATHERED MANCOS SHALE, (MUDSTONE), olive gray, dry, grades to medium gray from 12 to 16 ft. |
| 15                     |             |             |               |                            |                | 16.0 MANCOS SHALE, dark gray, hard, dry, competent.                                               |
| 20                     |             |             |               |                            |                | 19.0 SHALE, dark gray, occasional shell fragments, dry, moderately fractured.                     |
| File: 93-200-1.log     |             |             |               |                            |                | Page 1 of 6                                                                                       |
| Date Drawn: 03/14/1994 |             |             |               |                            |                |                                                                                                   |

# MONITORING WELL COMPLETION LOG 31SW93-200-1

| Depth<br>(ft.)         | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                      | Description                                                                                                                                                           |
|------------------------|-------------|-------------|---------------|------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        |             |             |               |  |    | Lost core, 23.0 to 27.0 ft.                                                                                                                                           |
| 25                     |             |             |               |                                                                                    |    | 27.0 SHALE, same as above.                                                                                                                                            |
|                        |             |             |               |                                                                                    |    | 29.0 SHALE, moderately fractured. Very light gray from 28.9 to 29.0 ft., feels like talc (bentonite).                                                                 |
| 30                     |             |             |               |                                                                                    |   | Lost core, 32.5 to 34.0 ft.                                                                                                                                           |
|                        |             |             |               |                                                                                    |  | 34.0 DAKOTA SANDSTONE, dirty with silt and carbonaceous material, mottled dark and light gray, few fossil fragments, moist, fracture spacing is 2-3 in., bioturbated. |
| 35                     |             |             |               |                                                                                    |  | Lost core, 39.0 to 40.5 ft.                                                                                                                                           |
|                        |             |             |               |                                                                                    |  | 40.5 SANDSTONE, same as above, unfractured, with single wet fracture at 40.8 ft.                                                                                      |
| 40                     |             |             |               |                                                                                    |  | 43.0 SANDSTONE, same as above, unfractured, occasional fossil fragments.                                                                                              |
| 45                     |             |             |               |                                                                                    |  | Poor recovery 48.5 to 49.2 ft., sandy siltstone, gray, very fractured.                                                                                                |
|                        |             |             |               |                                                                                    |  | 49.2 SANDSTONE, silty, gray, fine to medium grained, with black silt/ carbonaceous laminae. Grades downward to fine grained sandstone.                                |
| 50                     |             |             |               |                                                                                    |                                                                                     |                                                                                                                                                                       |
| File: 93-200-1.log     |             |             |               |                                                                                    |                                                                                     | Page 2 of 6                                                                                                                                                           |
| Date Drawn: 03/14/1994 |             |             |               |                                                                                    |                                                                                     |                                                                                                                                                                       |



# MONITORING WELL COMPLETION LOG 3ISW93-200-1

| Depth<br>(Ft.) | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                     | Description                                                                                                                                                          |
|----------------|-------------|-------------|---------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 55             |             |             |               |  |  | 52.4 SANDSTONE, silty, fine grained, light gray, with black laminae, nonhorizontal bedding planes. Grades downward to a fine to medium grained sandstone at 53.0 ft. |
|                |             |             |               |                                                                                    |                                                                                    | 53.0 SANDSTONE, silty, light gray, fine to medium grained, with black carbonaceous laminae, wavy bedded, unfractured.<br>Lost core, 54.0 - 57.8 ft.                  |
|                |             |             |               |                                                                                    |                                                                                    | 57.8 MUDSTONE, carbonaceous, very fractured. From 58.4 to 58.6 ft., carbonaceous, with coal stringers.                                                               |
|                |             |             |               |                                                                                    |                                                                                    | 59.0 SANDSTONE, silty, with abundant carbonized fragments. Grades downward to sandy siltstone.                                                                       |
|                |             |             |               |                                                                                    |                                                                                    | 59.5 SILTSTONE, sandy, dark gray.                                                                                                                                    |
|                |             |             |               |                                                                                    |                                                                                    | 60.3 SILTSTONE, carbonaceous, dark gray/black, with frequent fine sand laminae.                                                                                      |
|                |             |             |               |                                                                                    |                                                                                    | 61.5 COAL, silty, low grade, with pyrite nodules.                                                                                                                    |
|                |             |             |               |                                                                                    |                                                                                    | 62.7 SILTSTONE, carbonaceous.                                                                                                                                        |
|                |             |             |               |                                                                                    |                                                                                    | Lost core, 63.0 to 63.5 ft.                                                                                                                                          |
|                |             |             |               |                                                                                    |                                                                                    | 63.5 Same as above.                                                                                                                                                  |
|                |             |             |               |                                                                                    |                                                                                    | 65.0 SANDSTONE, silty, gray, frequent black carbonaceous laminae, unfractured, dry                                                                                   |
|                |             |             |               |                                                                                    |                                                                                    | 68.0 SILTSTONE, dark gray, very fractured, dry, poor recovery. Carbonaceous mudstone from 69.6 to 71.4 ft.                                                           |
|                |             |             |               |                                                                                    |                                                                                    | 71.4 COAL, silty, trace of sand, dry, pyritized zones.                                                                                                               |
|                |             |             |               |                                                                                    |                                                                                    | 72.5 SILTSTONE, dry, gray to medium dark gray, very fractured, poor recovery.                                                                                        |
| 75             |             |             |               |                                                                                    |                                                                                    |                                                                                                                                                                      |
|                |             |             |               |                                                                                    |                                                                                    | 78.8 SANDSTONE, silty, dry.                                                                                                                                          |
| 80             |             |             |               |                                                                                    |                                                                                    | 79.2 SILTSTONE, dry fractured, poor recovery.                                                                                                                        |

File: 93-200-1.log

Date Drawn: 03/14/1994

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# MONITORING WELL COMPLETION LOG 31SW93-200-1

| Depth<br>(Ft.)         | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                               |
|------------------------|-------------|-------------|---------------|----------------------------|----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        |             |             |               |                            |                |                                                                                                                                                                           |
| 85                     |             |             |               |                            |                | Lost core, 83.0 to 83.5 ft.                                                                                                                                               |
|                        |             |             |               |                            |                | 83.5 SILTSTONE, medium gray, trace fine carbonized material, dry.                                                                                                         |
|                        |             |             |               |                            |                | Lost core, 88.0 to 89.0 ft.                                                                                                                                               |
| 90                     |             |             |               |                            |                | 89.0 SILTSTONE, carbonaceous, medium gray, dry, unfractured.                                                                                                              |
|                        |             |             |               |                            |                | 93.0 SANDSTONE, silty, fine to medium grained, with black carbonaceous laminae, pyrite nodules, dry.                                                                      |
|                        |             |             |               |                            |                | 93.6 SILTSTONE, sandy, dry, 2 to 3 in. fracture spacing.                                                                                                                  |
| 95                     |             |             |               |                            |                | 94.6 SANDSTONE, silty, gray, with black carbonaceous material.                                                                                                            |
|                        |             |             |               |                            |                | 95.0 SILTSTONE, sandy, with fine carbonaceous material.                                                                                                                   |
|                        |             |             |               |                            |                | 95.7 SANDSTONE, silty, fine to medium grained, with black carbonaceous laminae, unfractured, hard, dry, pyrite nodules, well cemented.                                    |
|                        |             |             |               |                            |                | 97.5 SILTSTONE, light gray, some carbonized fragments, grades downward to very fine grained sandstone.                                                                    |
| 100                    |             |             |               |                            |                | 98.0 SANDSTONE, silty, very fine grained, some carbonized plant fragments, dry, grades to a gray siltstone/mudstone.                                                      |
|                        |             |             |               |                            |                | 99.1 SILTSTONE, dry, hard, trace of carbonaceous material, trace of fine sand from 100.0 to 100.8 ft.                                                                     |
|                        |             |             |               |                            |                | 100.8 SANDSTONE, fine grained, well cemented, light gray, with frequent silt/carbonaceous laminae from 102 to 103 ft., wavy bedded, dry, mudstone from 101.6 to 101.7 ft. |
|                        |             |             |               |                            |                | 103.4 Interbedded sandstone and mudstone, dry.                                                                                                                            |
| 105                    |             |             |               |                            |                | 104.5 MUDSTONE, medium dark gray.                                                                                                                                         |
|                        |             |             |               |                            |                | 104.8 COAL, silty, pyrite nodules, dry.                                                                                                                                   |
|                        |             |             |               |                            |                | Lost core, 105.1 to 107.3 ft.                                                                                                                                             |
| 110                    |             |             |               |                            |                |                                                                                                                                                                           |
| File: 93-200-1.log     |             |             |               |                            |                | Page 4 of 6                                                                                                                                                               |
| Date Drawn: 03/14/1994 |             |             |               |                            |                |                                                                                                                                                                           |

# MONITORING WELL COMPLETION LOG 31SW93-200-1

| Depth<br>(Ft.)         | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                                                                                                                                                                    |  |  |
|------------------------|-------------|-------------|---------------|----------------------------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|
| 115                    |             |             |               |                            |                | 110.0 SILTSTONE/SANDSTONE, very fine grained, gray, some pyrite and carbonized plant debris, hard, wet.                                                                                                                                                                                                                                        |  |  |
|                        |             |             |               |                            |                | 111.3 Same as above, with abundant carbonaceous laminae, wavy bedded, 1 to 2 in. fracture spacing.                                                                                                                                                                                                                                             |  |  |
|                        |             |             |               |                            |                | 113.0 SANDSTONE, fine grained, well sorted with a trace of carbonized plant fragments, light gray, few carbonaceous laminae, moist to wet.                                                                                                                                                                                                     |  |  |
|                        |             |             |               |                            |                | 114.8 SANDSTONE, fine grained, medium gray with abundant carbonaceous laminae, hard.                                                                                                                                                                                                                                                           |  |  |
|                        |             |             |               |                            |                | 118.0 SANDSTONE, medium grained, abundant carbonized plant fragments, fractured, wet.                                                                                                                                                                                                                                                          |  |  |
|                        |             |             |               |                            |                | 117.4 SANDSTONE, dirty, medium to coarse grained, with graded cross bed sets, some carbonaceous stringers and laminae.                                                                                                                                                                                                                         |  |  |
|                        |             |             |               |                            |                | Pyrite cement at 118.0 ft. Decomposed sandstone from 118.2 to 118.3 ft., and 118.6 to 118.8 ft., saturated, some light green clay fragments. Some fine gravel from 119.8 to 120.0 ft.                                                                                                                                                          |  |  |
| 120                    |             |             |               |                            |                | 120.0 SANDSTONE, medium to coarse grained, light gray, well rounded quartz grains and dark, medium to coarse grained chert fragments. Some black carbonaceous laminae, light green, clayey, pore filling. At 121.3 ft, a very fine gravel horizon.                                                                                             |  |  |
|                        |             |             |               |                            |                | 121.3 SANDSTONE, fine to medium grained, gray, graded cross bed sets 1/2 in. thick, sloped bedding planes, wet.                                                                                                                                                                                                                                |  |  |
|                        |             |             |               |                            |                | 122.0 SANDSTONE, silty, with black chert fragments, scoured contact with overlying interval, trace carbonaceous material.                                                                                                                                                                                                                      |  |  |
| 125                    |             |             |               |                            |                | 122.9 MUDDSTONE, dark gray/black, chert texture/appearance, dry, (not hard enough to be chert).                                                                                                                                                                                                                                                |  |  |
|                        |             |             |               |                            |                | 123.3 SANDSTONE, dirty, fine grained, some chert fragments and carbonized material, very fine sized gravel.                                                                                                                                                                                                                                    |  |  |
|                        |             |             |               |                            |                | 124.5 BURRO CANYON FORMATION, SANDSTONE, fine to medium grained, friable, light gray/green, some dark chert fragments, light green clayey zones and pore fill. Sand grains are well sorted and well rounded quartz. Chert fragments are subangular, very fine gravel size. Scoured contact at 124.5 ft. and no carbonized material is below.   |  |  |
| 130                    |             |             |               |                            |                | 125.0 SANDSTONE, clean, quartzose, light gray, well sorted, well rounded, medium grained, friable, wet. Abundant dark gray chert fragments, coarse to very coarse sand size. Interval is cross bedded, pyrite at 127.2 ft., light green clay pore fill. From 127.2 to 127.9 ft., same as above with increased dark fine gravel content, moist. |  |  |
|                        |             |             |               |                            |                | 127.9 SILTSTONE/MUDDSTONE, light green, trace of fine gravel. Grades downward to light gray/green siltstone/very fine sandstone, slightly moist.                                                                                                                                                                                               |  |  |
| 135                    |             |             |               |                            |                | 130.0 SANDSTONE, fine grained, friable, moist, greenish gray (5 GY 6/1), slightly calcareous from 130 to 131 ft. Grades downward to very fine grained sandstone, noncalcareous at 134.0 ft.                                                                                                                                                    |  |  |
|                        |             |             |               |                            |                | 135.7 SANDSTONE, becomes fine grained and contains green and black chert pebbles, some sand is medium grained.                                                                                                                                                                                                                                 |  |  |
| 140                    |             |             |               |                            |                | 138.0 SANDSTONE, fine grained, greenish gray (5G 6/1), moist. Brown chert fragments to 1/2 in. diameter, friable. 45 degree fracture at 138.2 ft. Trace of pyrite along bedding.                                                                                                                                                               |  |  |
| File: 93-200-1.log     |             |             |               |                            |                | Page 5 of 6                                                                                                                                                                                                                                                                                                                                    |  |  |
| Date Drawn: 03/14/1994 |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                                |  |  |

# MONITORING WELL COMPLETION LOG 31SW93-200-1

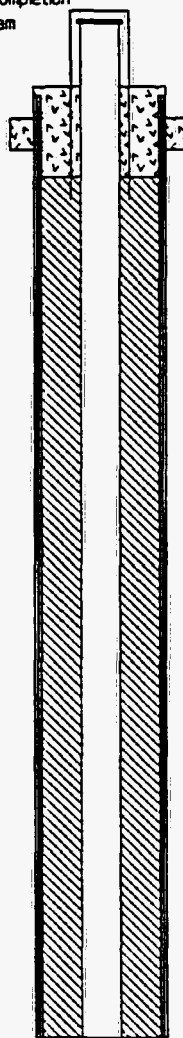
| Depth<br>(Ft.)         | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                                                                                                                                                                |
|------------------------|-------------|-------------|---------------|----------------------------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 145                    |             |             |               |                            |                | 140.0 SANDSTONE, friable, fine grained, varies in color from light olive gray (5Y 6/1) to greenish gray (5GY 6/1), slightly moist, scattered dark chert pebbles at 143.0 ft. Becomes siltstone, dry, greenish gray (5G 6/1), from 143.2 to 145.0 ft.                                                                                       |
|                        |             |             |               |                            |                | Lost core, 145.0 to 150.0 ft.                                                                                                                                                                                                                                                                                                              |
| 150                    |             |             |               |                            |                | 150.0 SILTSTONE, to very fine grained sandstone, greenish gray (5GY 6/1), noncalcareous, lost core from 150.5 to 151.0 ft. At 151.0 ft., is very fine grained sandstone, light greenish gray (5GY 8/1), with scattered greenish gray (5GY 6/1), siltstone noncalcareous. From 153.0 to 153.5 ft., pyrite occurs along irregular fractures. |
| 155                    |             |             |               |                            |                | 153.5 SANDSTONE, fine grained, greenish gray (5GY 6/1), slightly moist.                                                                                                                                                                                                                                                                    |
|                        |             |             |               |                            |                | 156.0 SANDSTONE, becomes lighter colored, light greenish gray (5GY 8/1), and greenish gray (5G 6/1). Thin clay layers are scattered as are small varicolored chert pebbles up to 1/4 in. diameter.                                                                                                                                         |
| 160                    |             |             |               |                            |                | 157.5 Fine grained SANDSTONE with varicolored chert pebbles to 1/2 in. diameter. Rough 45 degree fracture at 158.4 ft. Color is light gray (N7), well rounded quartz grains, core is moist, chert pebbles are more numerous, noncalcareous.                                                                                                |
|                        |             |             |               |                            |                | 160.2 SANDSTONE, fine grained, friable, contains layers of silt, medium gray (N5), wet. At 161.0 ft, becomes well cemented, fine grained sandstone, light gray (N7). Sandstone coarsens downward to 163.0 ft. with increasing chert pebbles to 1/2 in. diameter, wet. Rough 30 degree fracture at 162.6 and 162.8 ft.                      |
| 165                    |             |             |               |                            |                | 163.0 SANDSTONE, fine to medium grained, with salt/pepper appearance w/varicolored chert and feldspar grains and rounded quartz grains. 10 degree fracture at 164.1, friable at 164.6 to 164.8 ft.                                                                                                                                         |
|                        |             |             |               |                            |                | 165.2 SANDSTONE, light gray (N7), very fine grained, with trace of pyrite in mats and some siltstone, greenish gray (5GY 6/1), damp.                                                                                                                                                                                                       |
| 170                    |             |             |               |                            |                | 167.0 SANDSTONE, very fine grained, light greenish gray (5GY 8/1), damp, At 167.7 ft. the sandstone becomes friable, moist, has trace of pyrite grains disseminated. Rough 60 degree fracture at 169.0 ft. Sandstone is friable to 169.2 ft., then becomes well cemented, damp to moist, noncalcareous.                                    |
|                        |             |             |               |                            |                | Total depth drilled was 170.0 feet.                                                                                                                                                                                                                                                                                                        |
| File: 93-200-1.log     |             |             |               |                            |                | Page 6 of 6                                                                                                                                                                                                                                                                                                                                |
| Date Drawn: 03/14/1994 |             |             |               |                            |                |                                                                                                                                                                                                                                                                                                                                            |

# **MONITORING WELL COMPLETION LOG 31SW93-200-2**

|                                        |                                      |                                       |
|----------------------------------------|--------------------------------------|---------------------------------------|
| Project: Monticello Mill Tailings Site | North Coordinate (ft.): 10243.3      | Date Drilled: 9/2, 24, 25/93          |
| Location: Monticello, Utah             | East Coordinate (ft.): 20881.2       | Drilling Method: Air Rotary           |
| Site: Millsite                         | Ground Elevation (ft. MSL): 6894.9   | Sampling Method: Cuttings             |
| Total Depth (ft.): 122.0               | Measuring Point Elev. (ft.): 6897.36 | Development Date: 10/31-11/17/93      |
| Auger Stem Size (in.): NA              | Auger Head Size (in.): NA            | Water Level (ft. BGL): 112.7, 9/26/93 |

|                                    |                       |                                     |
|------------------------------------|-----------------------|-------------------------------------|
| <b>WELL INSTALLATION:</b>          | <b>INTERVAL (ft.)</b> | <b>BIT SIZES (in.)</b>              |
| Blank Casing: 4 in. SCH 80 PVC     | -2.46 to 111.6        | 12 1/4 in. Rotary from 0 to 20.0    |
| Screen: 4 in. SCH 80 PVC           | 111.6 to 121.6        | 7 7/8 in. Rotary from 20.0 to 122.0 |
| Slot Size: 0.020 in.               |                       |                                     |
| End Cap: 4 in. SCH 80 PVC          | 121.6 to 122.0        | <b>SURFACE CASING (ft.)</b>         |
| Grout: Enviroplug                  | 3.0 to 104.5          | 8 5/8 in. Steel from 0 to 20.0      |
| Sealant: 1/4 in. Bentonite Pellets | 104.5 to 107.5        |                                     |
| Sand Pack (U): #20/40              | 107.5 to 108.5        |                                     |
| Sand Pack (L): #10/20              | 108.5 to 122.0        |                                     |

Comments: Slow recovery.

| Depth<br>(ft.)         | Blows/8-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                         | Graphic<br>Log | Description                                                                                                                                                                                              |
|------------------------|-------------|-------------|---------------|------------------------------------------------------------------------------------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        |             |             |               |  |                | Logged By: T. Bartlett                                                                                                                                                                                   |
|                        |             |             |               |                                                                                    |                | SILTY SAND, SM, very dry, brittle, firm. Poorly sorted with small amount of gravel, brown (5YR 4/2), loess.                                                                                              |
|                        |             |             |               |                                                                                    |                | 2.0 GRAVEL, GM, poorly graded, sand/silt mixture, yellow/brown (10YR 5/6), dry.                                                                                                                          |
| 5                      |             |             |               |                                                                                    |                | 5.0 Same as above, with large cobbles.                                                                                                                                                                   |
|                        |             |             |               |                                                                                    |                | 6.0 Same as above, large boulders,                                                                                                                                                                       |
|                        |             |             |               |                                                                                    |                | 6.5 SANDY SILT, ML, dry, slightly plastic, small amount gravel (<10%), yellow/brown (10YR 5/6).                                                                                                          |
| 10                     |             |             |               |                                                                                    |                | 8.0 Large boulders, refusal. NOTE: After moving 50 ft. to east, hit boulders and refusal at about 4 ft., 3rd attempt augered to 10 ft. and found fewer boulders at 8 to 10 ft., otherwise same as above. |
|                        |             |             |               |                                                                                    |                | 10.5 WEATHERED MANCOS SHALE, calcareous, dry, brittle, very weathered shale, medium dark gray (5YR 5/1).                                                                                                 |
|                        |             |             |               |                                                                                    |                | 12.0 Same as above, easy augering (very weathered).                                                                                                                                                      |
| 15                     |             |             |               |                                                                                    |                | 15.0 WEATHERED MANCOS SHALE, only slightly weathered calcareous shale with a few small fossil inclusions, dark gray (5YR 4/1).                                                                           |
|                        |             |             |               |                                                                                    |                | 18.0 MANCOS SHALE, bedrock, solid, dry, dark gray (5YR 4/1).                                                                                                                                             |
| 20                     |             |             |               |                                                                                    |                | NOTE: Lithologic description from 0 to 20.0 ft. was taken from the nearby 93-200-4 boring. --                                                                                                            |
| File: 93-200-2.LOG     |             |             |               |                                                                                    |                | Page 1 of 5                                                                                                                                                                                              |
| Date Drawn: 03/10/1994 |             |             |               |                                                                                    |                |                                                                                                                                                                                                          |

# MONITORING WELL COMPLETION LOG 31SW93-200-2

| Depth<br>(Ft.) | Blows/6-in. | Sample Int. | Sample No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                      |
|----------------|-------------|-------------|------------|----------------------------|----------------|--------------------------------------------------------------------------------------------------|
|                |             |             |            |                            |                |                                                                                                  |
|                |             |             |            |                            |                | 20.0 SHALE, medium gray, hard, dry, trace of silt                                                |
|                |             |             |            |                            |                | -- NOTE: Lithology from 20 to 122 ft. is from 93-200-2 borehole drill cuttings. --               |
| 25             |             |             |            |                            |                |                                                                                                  |
| 30             |             |             |            |                            |                | 30.0 CLAYSTONE, bentonitic, light gray, soft, with medium grained sand.                          |
|                |             |             |            |                            |                | 31.0 SHALE, medium gray, dry, hard, trace of silt.                                               |
| 35             |             |             |            |                            |                |                                                                                                  |
| 40             |             |             |            |                            |                | 38.0 DAKOTA SANDSTONE, silty, with carbonized material, mottled light gray and black, hard, dry. |
| 45             |             |             |            |                            |                |                                                                                                  |
| 50             |             |             |            |                            |                | 48.0 SILTSTONE, rapid penetration rate, less drilling dust, moist.                               |

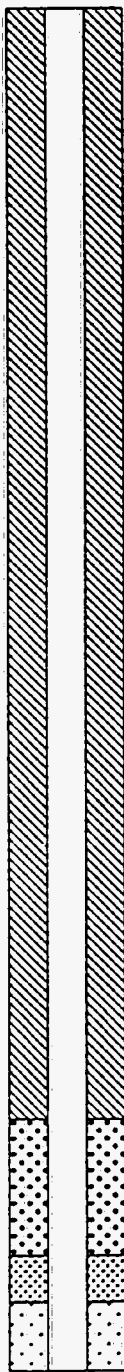

|                        |             |
|------------------------|-------------|
| File: 93-200-2.LOG     | Page 2 of 5 |
| Date Drawn: 03/10/1994 |             |

# MONITORING WELL COMPLETION LOG 31SW93-200-2

| Depth<br>(Ft.)         | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                |
|------------------------|-------------|-------------|---------------|----------------------------|----------------|--------------------------------------------------------------------------------------------------------------------------------------------|
|                        |             |             |               |                            |                | 50.0 SANDSTONE, silty, fine to medium grained, light gray sand and black silt/carbonaceous laminae, nonplanar bedding surfaces, hard, dry. |
| 55                     |             |             |               |                            |                | 54.0 MUDSTONE, carbonaceous, rapid penetration rate, much black dust.                                                                      |
|                        |             |             |               |                            |                | 58.5 SANDSTONE, silty sandstone to sandy siltstone with abundant carbonaceous material, dry, hard.                                         |
| 60                     |             |             |               |                            |                | 61.0 SILTSTONE / COAL, interbedded, black, rapid penetration rate, dry.                                                                    |
|                        |             |             |               |                            |                | 66.0 SANDSTONE, silty, with black carbonaceous laminae, hard.                                                                              |
|                        |             |             |               |                            |                | 68.0 SILTSTONE, dark gray, moist, rapid penetration rate.                                                                                  |
| 70                     |             |             |               |                            |                | Decreased penetration rate from 70 to 71 ft., much dust.                                                                                   |
|                        |             |             |               |                            |                | 71.0 SILTY COAL / SILTSTONE, interbedded, silty coal and siltstones, black to dark gray, rapid penetration rate, some moist cuttings.      |
| 75                     |             |             |               |                            |                |                                                                                                                                            |
|                        |             |             |               |                            |                | 78.0 SANDSTONE, silty sandstone, hard, light gray with carbonaceous flecks.                                                                |
| 80                     |             |             |               |                            |                | 79.5 SILTSTONE, medium gray, trace carbonaceous material, rapid penetration rate.                                                          |
| File: 93-200-2.LOG     |             |             |               |                            |                | Page 3 of 5                                                                                                                                |
| Date Drawn: 03/10/1994 |             |             |               |                            |                |                                                                                                                                            |

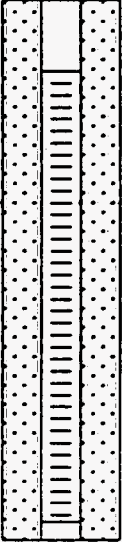



# MONITORING WELL COMPLETION LOG 31SW93-200-2

| Depth<br>(ft.)         | Blows/ft.-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                         | Graphic<br>Log                                                                     | Description                                                                                                            |
|------------------------|---------------|-------------|---------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------|
| 85                     |               |             |               |  |  | 88.0 Same as above with thin carbonaceous siltstone layers.                                                            |
| 90                     |               |             |               |                                                                                    |                                                                                    | 92.0 SANDSTONE / SILTSTONE, interbedded silty sandstones and siltstones contain black carbonaceous laminae and debris. |
| 95                     |               |             |               |                                                                                    |                                                                                    |                                                                                                                        |
| 100                    |               |             |               |                                                                                    |                                                                                    | 100.0 SANDSTONE, silty, light gray, fine to medium grained with carbonaceous material / laminae, hard.                 |
| 105                    |               |             |               |                                                                                    |                                                                                    | 104.0 COAL / SILTY COAL,<br>Rapid penetration rate from 104.5 to 107 ft., black dust.                                  |
|                        |               |             |               |                                                                                    |                                                                                    | 107.0 SILTY SANDSTONE / SANDY SILTSTONE, moist from 109 to 110 ft.                                                     |
| 110                    |               |             |               |                                                                                    |                                                                                    |                                                                                                                        |
| File: 93-200-2.LOG     |               |             |               |                                                                                    |                                                                                    | Page 4 of 5                                                                                                            |
| Date Drawn: 03/10/1994 |               |             |               |                                                                                    |                                                                                    |                                                                                                                        |



# MONITORING WELL COMPLETION LOG 31SW93-200-2

| Depth<br>(Ft.) | Blows/6-In. | Sample Int. | Sample<br>No.                                                     | Well Completion<br>Diagram                                                        | Graphic<br>Log                                                                    | Description                                                                                                                     |
|----------------|-------------|-------------|-------------------------------------------------------------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------|
| 115            |             |             |                                                                   |  |  | 110.0 SANDSTONE, fine to medium grained, wet, variable amounts of carbonized plant debris and carbonaceous laminae / stringers. |
| 120            |             |             | 120.0 Same as above with some medium to coarse grained sandstone. |                                                                                   |                                                                                   |                                                                                                                                 |
| 125            |             |             | Total depth at 122.0 ft.                                          |                                                                                   |                                                                                   |                                                                                                                                 |
| 130            |             |             |                                                                   |                                                                                   |                                                                                   |                                                                                                                                 |
| 135            |             |             |                                                                   |                                                                                   |                                                                                   |                                                                                                                                 |
| 140            |             |             |                                                                   |                                                                                   |                                                                                   |                                                                                                                                 |

File: 93-200-2.LOG

Date Drawn: 03/10/1994

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# **MONITORING WELL COMPLETION LOG 31SW93-200-3**

|                                        |                                      |                                     |
|----------------------------------------|--------------------------------------|-------------------------------------|
| Project: Monticello Mill Tailings Site | North Coordinate (ft.): 10234.9      | Date Drilled: 9/1-2, 9/25/93        |
| Location: Monticello, Utah             | East Coordinate (ft.): 20855.2       | Drilling Method: Air Rotary         |
| Site: Millsite                         | Ground Elevation (ft. MSL): 6895.1   | Sampling Method: Cuttings           |
| Total Depth (ft.): 35.0                | Measuring Point Elev. (ft.): 6897.78 | Development Date: 10/27-11/23/93    |
| Auger Stem Size (in.): NA              | Auger Head Size (in.): NA            | Water Level (ft. BGL): Dry, 9/26/93 |

|                                    |                       |                                    |
|------------------------------------|-----------------------|------------------------------------|
| <b>WELL INSTALLATION</b>           | <b>INTERVAL (ft.)</b> | <b>BIT SIZES (in.)</b>             |
| Blank Casing: 2 in. SCH 80 PVC     | -2.68 to 24.65        | 12 1/4 in. Rotary from 0 to 20.0   |
| Screen: 2 in. SCH 80 PVC           | 24.65 to 34.65        | 7 7/8 in. Rotary from 20.0 to 35.0 |
| Slot Size: 0.020 in.               |                       |                                    |
| End Cap: 2 in. SCH 80 PVC          | 34.65 to 35.0         | <b>SURFACE CASING (ft.)</b>        |
| Grout: Enviroplug                  | 3.0 to 19.3           | 8 5/8 in. Steel from -8 to 20.0    |
| Sealant: 1/4 in. Bentonite Pellets | 19.3 to 21.4          |                                    |
| Sand Pack (U): #20/40              | 21.4 to 22.2          |                                    |
| Sand Pack (L): #10/20              | 22.2 to 35.0          |                                    |

Comments: Well is extremely slow to recover.

| Depth<br>(ft.)                                                               | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                      |
|------------------------------------------------------------------------------|-------------|-------------|---------------|----------------------------|----------------|----------------------------------------------------------------------------------|
|                                                                              |             |             |               |                            |                | Logged By: T. Bartlett                                                           |
| 5                                                                            |             |             |               |                            |                | Igneous cobbles and boulders in silty clay matrix, dry. Very difficult drilling. |
| 10                                                                           |             |             |               |                            |                | 10.0 WEATHERED MANCOS SHALE, olive/gray, dry                                     |
| 15                                                                           |             |             |               |                            |                | 12.0 Same as above, medium gray.                                                 |
| 20                                                                           |             |             |               |                            |                | 16.0 MANCOS SHALE, dark gray, hard, dry. Penetration rate decreased at 16.0 ft.  |
| <div> <div>File: 93-200-3.LOG</div> <div>Date Drawn: 03/10/1994</div> </div> |             |             |               |                            |                | Page 1 of 2                                                                      |

# MONITORING WELL COMPLETION LOG 31SW93-200-3

| Depth (ft.) | Blows/6-In. | Sample Int. | Sample No. | Well Completion Diagram | Graphic Log | Description                                                                                                                                                                                                                                                                                    |
|-------------|-------------|-------------|------------|-------------------------|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 25          |             |             |            |                         |             | <p>20.0 SHALE, dark gray, occasional shell fragments, dry, moderately fractured.</p> <p>Lost core, 23.0 to 27.0.</p> <p>NOTE: Lithology from 20 to 35 ft. was taken from the 93-200-1 borehole log. -</p> <p>From 28.9 to 29.0 ft. is a bentonite zone.</p> <p>Lost core, 32.5 to 34.0 ft.</p> |
| 30          |             |             |            |                         |             |                                                                                                                                                                                                                                                                                                |
| 35          |             |             |            |                         |             | <p>34.0 DAKOTA SANDSTONE, dirty, with silt and carbonaceous material, mottled dark and light gray, few fossil fragments, moist, fracture spacing is 2 to 3 in., bioturbated.</p> <p>Total depth at 35.0 ft.</p>                                                                                |
| 40          |             |             |            |                         |             |                                                                                                                                                                                                                                                                                                |
| 45          |             |             |            |                         |             |                                                                                                                                                                                                                                                                                                |
| 50          |             |             |            |                         |             |                                                                                                                                                                                                                                                                                                |

File: 93-200-3.LOG

Date Drawn: 03/10/1994

Page 2 of 2

# MONITORING WELL COMPLETION LOG 31SW93-200-4

Project: Monticello Mill Tailings Site  
 Location: Monticello, Utah  
 Site: Millsite  
 Total Depth (ft.): 24.5  
 Auger Stem Size (in.): 10 1/4

North Coordinate (ft.): 10228.27  
 East Coordinate (ft.): 20889.52  
 Ground Elevation (ft. MSL): 6895.20  
 Measuring Point Elev. (ft.): 6897.71  
 Auger Head Size (in.): 10 5/8

Date Drilled: 8/6/93  
 Drilling Method: Hollow Stem Augers  
 Sampling Method: Split Spoon  
 Development Date: 10/27-11/23/93  
 Water Level (ft. BGL): 24.06, 12/14/93

**WELL INSTALLATION**  
 Blank Casing: 2 in. SCH 80 PVC  
 Screen: 2 in. SCH 80 PVC  
 Slot Size: 0.010 in.  
 End Cap: 2 in. SCH 80 PVC  
 Grout: Enviroplug  
 Sealant: 1/4 in. Bentonite Pellets  
 Sand Pack (U): #20/40  
 Sand Pack (L): #10/20

**INTERVAL (ft.)**  
 -2.51 to 14.25  
 14.25 to 23.35  
 23.35 to 24.5  
 1.0 to 9.0  
 9.0 to 11.0  
 11.0 to 12.0  
 12.0 to 24.5

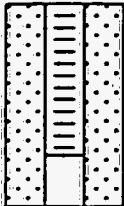
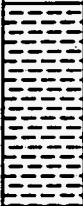
**BIT SIZES (in.)**  
 Not Applicable

**SURFACE CASING (ft.)**  
 Not Applicable

Comments: Well installed 8/23/93. Some recovery.

| Depth<br>(ft.)         | Blows/6-in. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram | Graphic<br>Log | Description                                                                                                                                                                                              |
|------------------------|-------------|-------------|---------------|----------------------------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                        |             |             |               |                            |                | Logged By: D. Miller                                                                                                                                                                                     |
| 5-9                    |             | X           |               |                            |                | SILTY SAND, SM, very dry, brittle, firm. Poorly sorted with small amount of gravel, brown (5YR 4/2), loess.                                                                                              |
| 14-26                  |             | X           |               |                            |                | 2.0 GRAVEL, GM, poorly graded, sand/silt mixture, yellow/brown (10YR 5/8), dry.                                                                                                                          |
| 5                      |             | X           |               |                            |                | 5.0 Same as above, with large cobbles.                                                                                                                                                                   |
| 22-33                  |             | X           |               |                            |                | 6.0 Same as above, large boulders.                                                                                                                                                                       |
| 50/3"                  |             |             |               |                            |                | 6.5 SANDY SILT, ML, dry, slightly plastic, small amount gravel (<10%), yellow/brown (10YR 5/8).                                                                                                          |
| 10                     |             | X           |               |                            |                | 8.0 Large boulders, refusal. NOTE: After moving 50 ft. to east, hit boulders and refusal at about 4 ft., 3rd attempt augered to 10 ft, and found fewer boulders at 8 to 10 ft., otherwise same as above. |
| 5-33                   |             | X           |               |                            |                | 10.5 WEATHERED MANCOS SHALE, calcareous, dry, brittle, very weathered shale, medium dark gray (5YR 5/1).                                                                                                 |
| 50/3"                  |             |             |               |                            |                | 12.0 Same as above, easy augering (very weathered).                                                                                                                                                      |
| 15                     |             | X           |               |                            |                | 15.0 WEATHERED MANCOS SHALE, only slightly weathered calcareous shale with a few small fossil inclusions, dark gray (5YR 4/1).                                                                           |
| 50/4"                  |             |             |               |                            |                | 16.0 MANCOS SHALE, bedrock, solid, dry, dark gray (5YR 4/1).                                                                                                                                             |
| 20                     |             |             |               |                            |                | Water encountered at 19.0 ft.                                                                                                                                                                            |
| File: 92-200-4.log     |             |             |               |                            |                | Page 1 of 2                                                                                                                                                                                              |
| Date Drawn: 03/10/1994 |             |             |               |                            |                |                                                                                                                                                                                                          |

# MONITORING WELL COMPLETION LOG 31SW93-200-4

| Depth<br>(ft.) | Blows/6-In. | Sample Int. | Sample<br>No. | Well Completion<br>Diagram                                                        | Graphic<br>Log                                                                    | Description                            |
|----------------|-------------|-------------|---------------|-----------------------------------------------------------------------------------|-----------------------------------------------------------------------------------|----------------------------------------|
|                |             |             |               |                                                                                   |                                                                                   |                                        |
|                |             |             |               |  |  | 20.0 SHALE, very hard, moist cuttings. |
| 25             |             |             |               |                                                                                   |                                                                                   | Total depth at 24.5 ft.                |
| 30             |             |             |               |                                                                                   |                                                                                   |                                        |
| 35             |             |             |               |                                                                                   |                                                                                   |                                        |
| 40             |             |             |               |                                                                                   |                                                                                   |                                        |
| 45             |             |             |               |                                                                                   |                                                                                   |                                        |
| 50             |             |             |               |                                                                                   |                                                                                   |                                        |

File: 92-200-4.log
Page 2 of 2

Date Drawn: 03/10/1994

Appendix C

**Appendix C**  
**Program Directives**



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## Program Directive

MMTS - OU III

Program/Project

Directive No. MSG-99-01

Task Order No. MAC99-03 (Task No. 301508001)

Initiated By: Tim Bartlett, Field Supervisor, MACTEC-ERS

**Directive Subject:** (1) Changes to ground water sample and water level measurement locations. (2) Temporary change to surface water location W-4 for the collection of unfiltered samples for metals and radionuclide analyses.

**Justification and Associated New Task Changes:** (1) Installation of temporary wells downgradient of the PeRT wall have been completed (location map and Well Data Summary attached) allowing for preliminary information to be gathered during the July sampling event. (2) Location W-4 is in an area of reconstruction and not accessible for sampling at this time.

**Organization(s) Affected:** Field sampling personnel and GJO Analytical Laboratory

**Affected Documents:**

*MMTS, OU III, Interim Remedial Action Work Plan, (Draft) May 1999, (MAC-MSG 2.2.4)*

*MMTS, OU III, Interim Remedial Action Surface Water and Ground Water Monitoring Plan, Rev. 2, July 1999 (MAC-MSGRAP 1.3.5-1)*

**Directive:** (1) Add temporary well locations T99-01, T99-03, and T99-05 and existing well locations 92-09, 95-03, P92-01, and P92-02 to the July 1999 quarterly sampling event.

Measure the water levels in temporary wells T99-01, T99-02, T99-03, T99-05, T99-06, T99-07, and T99-10. Water levels for the existing wells will be measured as specified in the *OU III, Interim Remedial Action Surface Water and Ground Water Monitoring Plan*. Temporary wells T99-01, T99-03, and T99-05 were the only locations where water was present at the time of drilling and installation in June 1999. If water is present in wells T99-02, T99-06, T99-07, and T99-10 samples will be collected. Sampling and analysis requirements for the temporary wells and additional existing wells are specified in Section 3.1.5 of the *OU III Interim Remedial Action Work Plan*.

(2) Collect unfiltered samples for metals and radionuclide analysis at location SW92-06 in place of the W-4 location identified in Section 4.3.2 of the *OU III, Interim Remedial Action Surface Water and Ground Water Monitoring Plan*. If SW92-06 is not accessible the samples should be collected from the Sorenson Site location.

**Review and Concurrence:**



Kristen McClellan, OU III Project Manager

**Task Order Manager Approval to Issue:**



Mike Butherus, Manager, Major Projects

7/19/99

**Effective Date:** July 19, 1999

**Expiration Date:** September 30, 1999

Distribution: w/ Attachments  
Task Order Managers Directive Log  
Jalane Glasgow - Record File MSG 1.14  
Holders of all affected documents  
Cathy Kelleher (2 copies) - Project Administrative Record

Monticello IRA Temporary Well Data Summary.

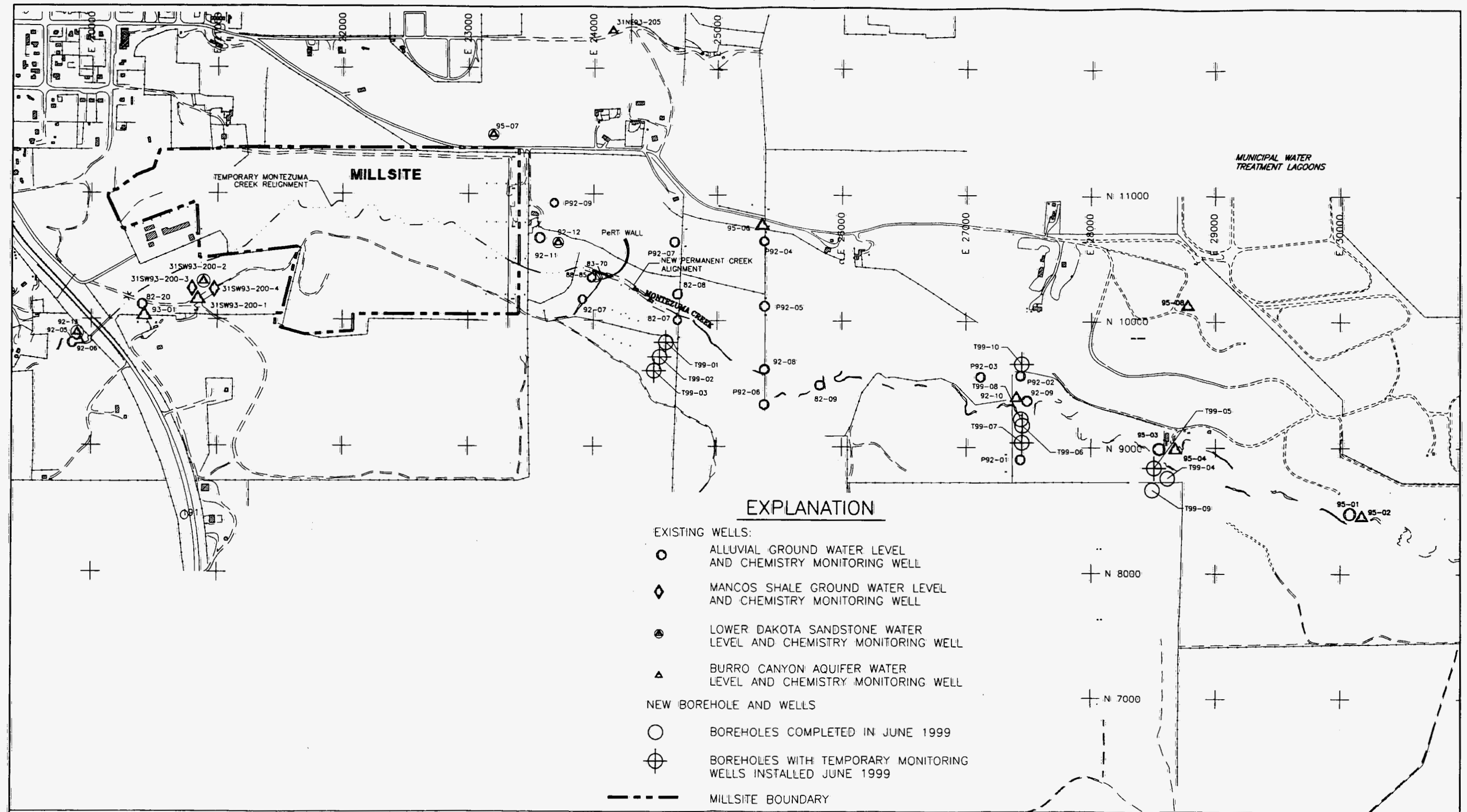
| Location | Northing | Easting | Stickup<br>[ft] | Depth<br>Drilled [ft] | Bottom of<br>Screen [ft bgs] | Bottom of<br>Screen [ft btoc] | Depth to<br>Bedrock [ft bgs] | Depth to<br>Water [ft btoc] | Saturated<br>Thickness [ft] |
|----------|----------|---------|-----------------|-----------------------|------------------------------|-------------------------------|------------------------------|-----------------------------|-----------------------------|
| T99-01   | 9824.8   | 24580.0 | 1.28            | 30                    | 28.8                         | 30.1                          | 29                           | 27.71                       | 2.6                         |
| T99-02   | 9708.6   | 24530.3 | 3.53            | 31.8                  | 31.6                         | 35.1                          | 31                           | DRY                         | 0.0                         |
| T99-03   | 9597.8   | 24484.9 | 2.44            | 24.5                  | 22.8                         | 25.2                          | 22.25                        | 21.33                       | 3.4                         |
| T99-04   | 8757.4   | 28615.2 | NA              | 13                    | NA                           | NA                            | 13                           | NA                          | 0.0                         |
| T99-05   | 8838.3   | 28506.8 | 1.93            | 11.5                  | 11                           | 12.9                          | 10.7                         | 11.51                       | 1.1                         |
| T99-06   | 9173.9   | 27448.1 | 1.11            | 10.5                  | 8.4                          | 9.5                           | 8.7                          | DRY                         | 0.0                         |
| T99-07   | 9039.0   | 27444.3 | 2.44            | 10.5                  | 10.2                         | 12.6                          | 10.25                        | DRY                         | 0.0                         |
| T99-08   | 9224.6   | 27436.6 | NA              | 6.5                   | NA                           | NA                            | 5.25                         | NA                          | 0.8                         |
| T99-09   | 8663.5   | 28492.3 | NA              | 9                     | NA                           | NA                            | 9                            | NA                          | 0.0                         |
| T99-10   | 9660.0   | 27441.6 | 2.81            | 7.5                   | 7.3                          | 10.1                          | 7.2                          | DRY                         | 0.0                         |

Northings and Eastings per Monticello Projects Coordinate System

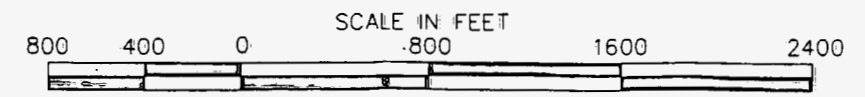
bgs = below ground surface

NA = not applicable

btoc = below top of casing

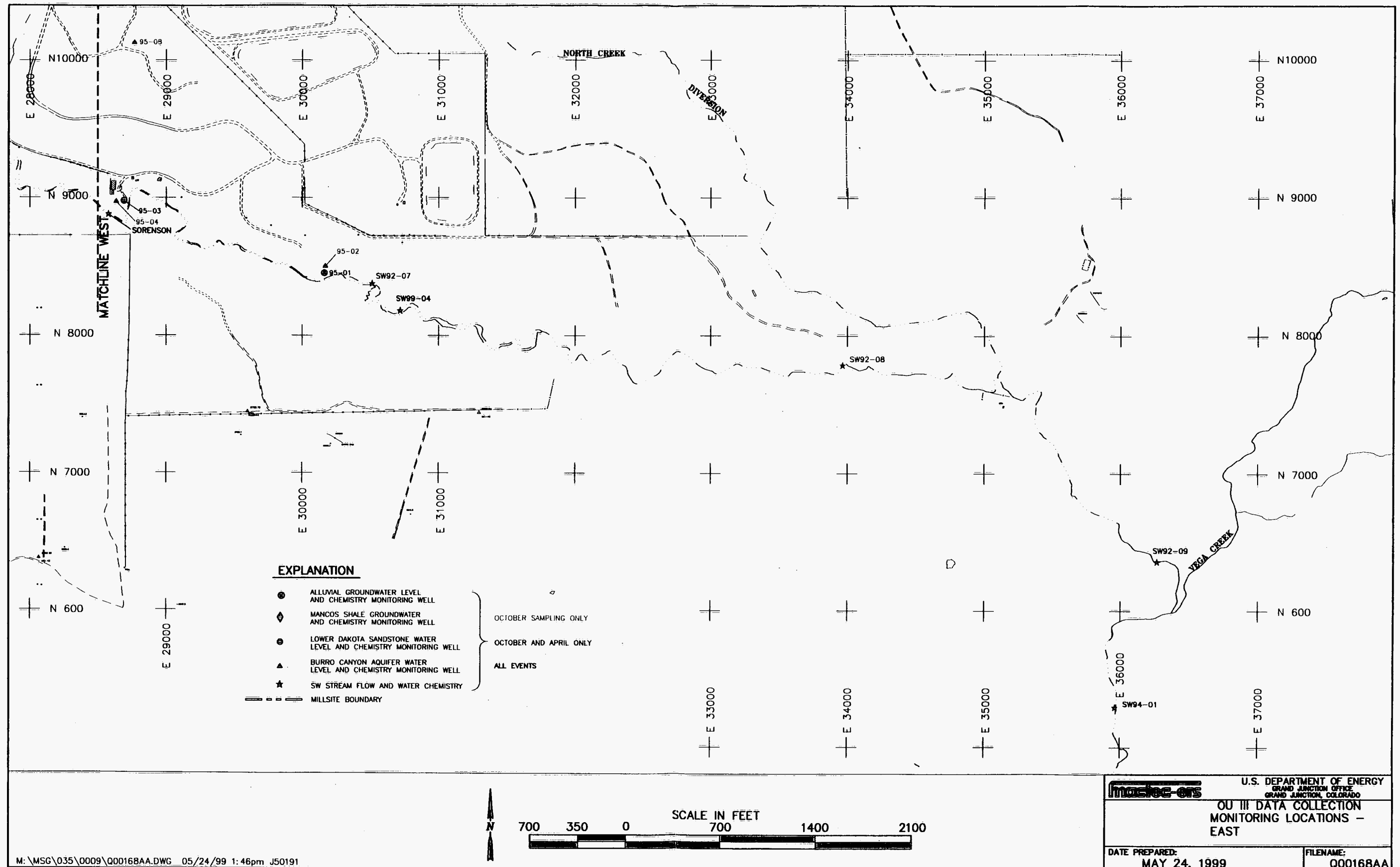


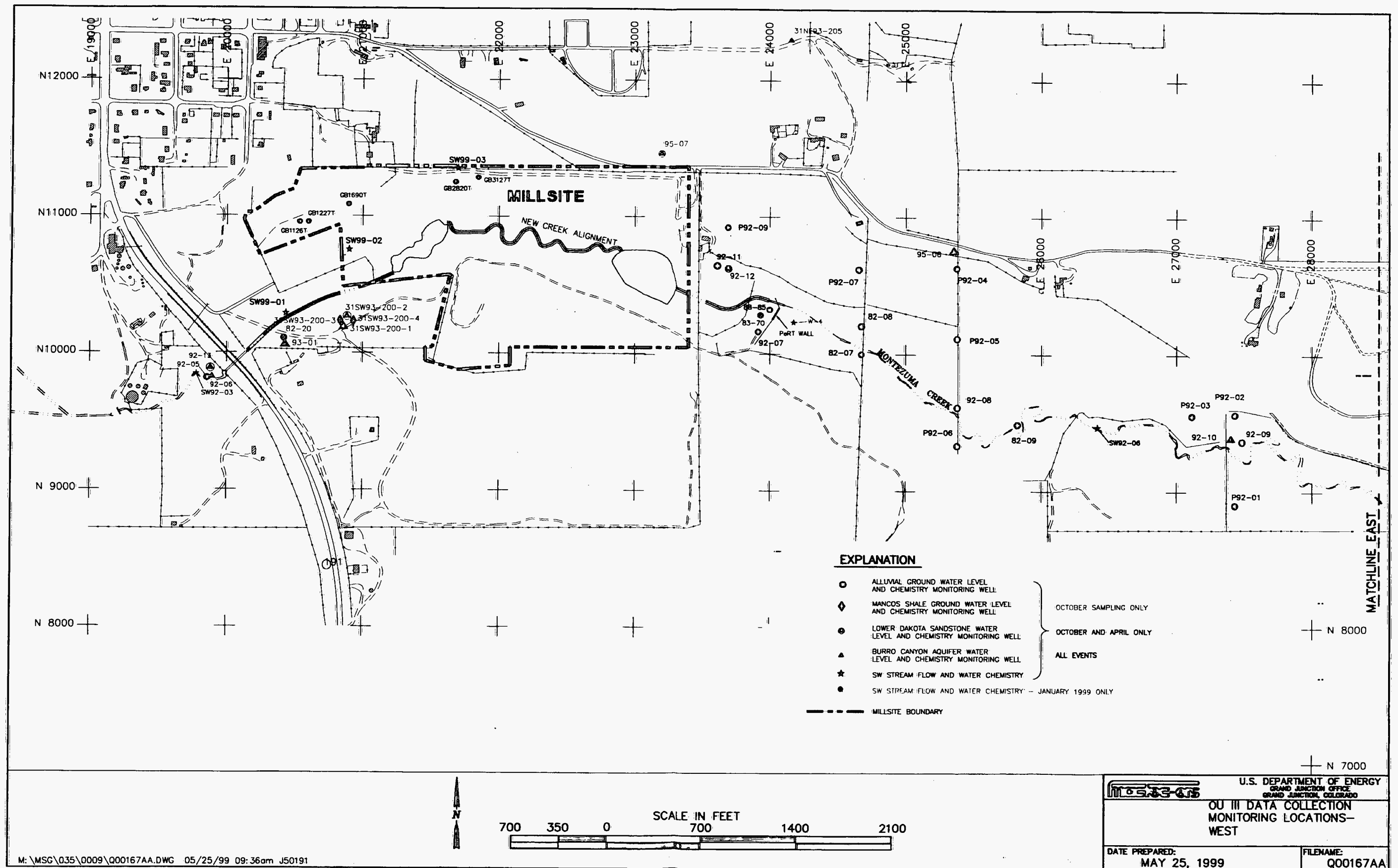
# EXPLANATION



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|                                                                                          |                       |                                                                                |
|------------------------------------------------------------------------------------------|-----------------------|--------------------------------------------------------------------------------|
|                                                                                          |                       | U.S. DEPARTMENT OF ENERGY<br>GRAND JUNCTION OFFICE<br>GRAND JUNCTION, COLORADO |
| OU III INTERIM REMEDIAL ACTION<br>BOREHOLE AND TEMPORARY WELLS<br>COMPLETED IN JUNE 1999 |                       |                                                                                |
| DATE PREPARED:<br>MAY 26, 1999                                                           | FILENAME:<br>Q00164AA |                                                                                |





## Program Directive

Program/Project: MMTS - OU III

Directive No. MSG-99-02

Task Order No. MAC99-03 (Task No. 301508001)

Initiated By: Tim Bartlett, Field Supervisor, MACTEC-ERS

**Directive Subject:** Changes to calibration frequencies at PeRT Wall well locations, clarification of turbidity monitoring for stabilization criteria, and extension of Program Directive MSG-99-01.

### Justification and Associated New Task Changes:

- (1) Calibration and operational checks of instruments used to monitor field parameters will not be required prior to sampling at each PeRT performance and tracer monitoring well. Additionally, field parameter monitoring and stabilization criteria are not required during well purging. These changes are incorporated into the sampling procedures because of the need to collect samples from the PeRT wells as contemporaneously as possible and considering instrument reliability through historical sampling, the close physical proximity of the shallow PeRT performance and tracer monitoring wells, and preliminary monitoring results indicating parameter stability.
- (2) Stabilization criteria for turbidity  $\leq 5$  NTUs is only required of the last reading when one borehole volume has been evacuated and other criteria (pH, Ec, and temperature) have stabilized over 3 successive readings.
- (3) OU III Program Directive MSG-99-01, regarding water level measurements and sampling of temporary wells and designated monitoring wells is extended indefinitely.

**Organization(s) Affected:** Field sampling personnel.

### Affected Documents:

*MMTS, OU III, Interim Remedial Action Surface Water and Ground Water Monitoring Plan*, Rev. 2, July 1999 (MAC-MSGRAP 1.3.5-1)

*MMTS, OU III Interim Remedial Action Work Plan*. (Draft) May 1999, (MAC-MSG 2.2.4)

**Directive:** (1) Calibrate the pH probe and perform operational checks of the Ec probe, oxidation-reduction potential (Eh) probe, turbidity meter, and dissolved oxygen (DO) meter/probe at the beginning of the day, prior to collection of the first sample; mid day; and at the end of the day, following the final sample collected on that day. Record field parameters before samples are collected. *Note:* Per the plan, a 3-point operational check of the Ec probe is required at the beginning and end of each day when samples are collected. (Reference Monitoring Plan pages 4-1 and 4-3 and table 4.2.2.1 page 4-4)

(2) The criteria for defining field parameter stability is as follows: stability is indicated when pH is within  $\pm 0.3$  pH units, and conductivity and temperature are within  $\pm 10$  percent of the most current 3 consecutive readings and when the correct purge volume has been evacuated and turbidity is  $\leq 5$  NTUs. Turbidity of  $\leq 5$  NTUs is not required over three successive readings. (Reference Monitoring Plan pages 4-1 and 4-3)

(3) Program Directive MSG-99-01 is extended until further notice. The following text is from the directive and has been modified as indicated:

Add temporary well locations T99-01, T99-03, and T99-05 and existing well locations 92-09, 95-03, P92-01, and P92-02 to the ~~July~~ quarterly sampling event(s).

Measure the water levels in temporary wells T99-01, T99-02, T99-03, T99-05, T99-06, T99-07, and T99-10. Water levels for the existing wells will be measured as specified in the *OU III, Interim Remedial Action Surface Water and Ground Water Monitoring Plan*. Temporary wells T99-01, T99-03, and T99-05 were the only locations where water was present at the time of drilling and installation in June 1999. If water is present in wells T99-02, T99-06, T99-07, and T99-10 samples will be collected. Sampling and analysis requirements for the temporary wells and additional existing wells are specified in Section 3.1.5 of the *OU III Interim Remedial Action Work Plan*.

Collect unfiltered samples for metals and radionuclide analysis at location SW92-06 in place of the W-4 location identified in Section 4.3.2 of the *OU III, Interim Remedial Action Surface Water and Ground Water Monitoring Plan*. If SW92-06 is not accessible the samples should be collected from the Sorenson Site location.

**Review and Concurrence:**

  
Kristen McClellan, OU III Project Manager

**Task Order Manager Approval to Issue:**

 9/9/99  
Mike Butherus, Manager, Major Projects

**Effective Date:** September 13, 1999

**Expiration Date:** September 30, 2000

**Distribution:**

Task Order Managers Directive Log  
Jalane Glasgow - Record File MSG 1.14  
Holders of all affected documents  
Cathy Kelleher (2 copies) - Project Administrative Record